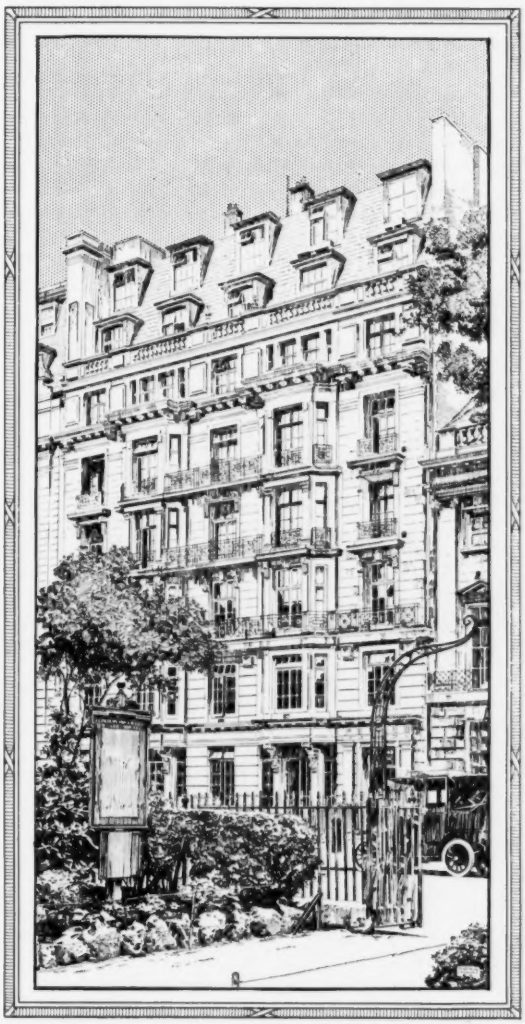
The ENGLISH ELECTRIC JOURNAL



Queen's House from Lincoln's Inn Fields.

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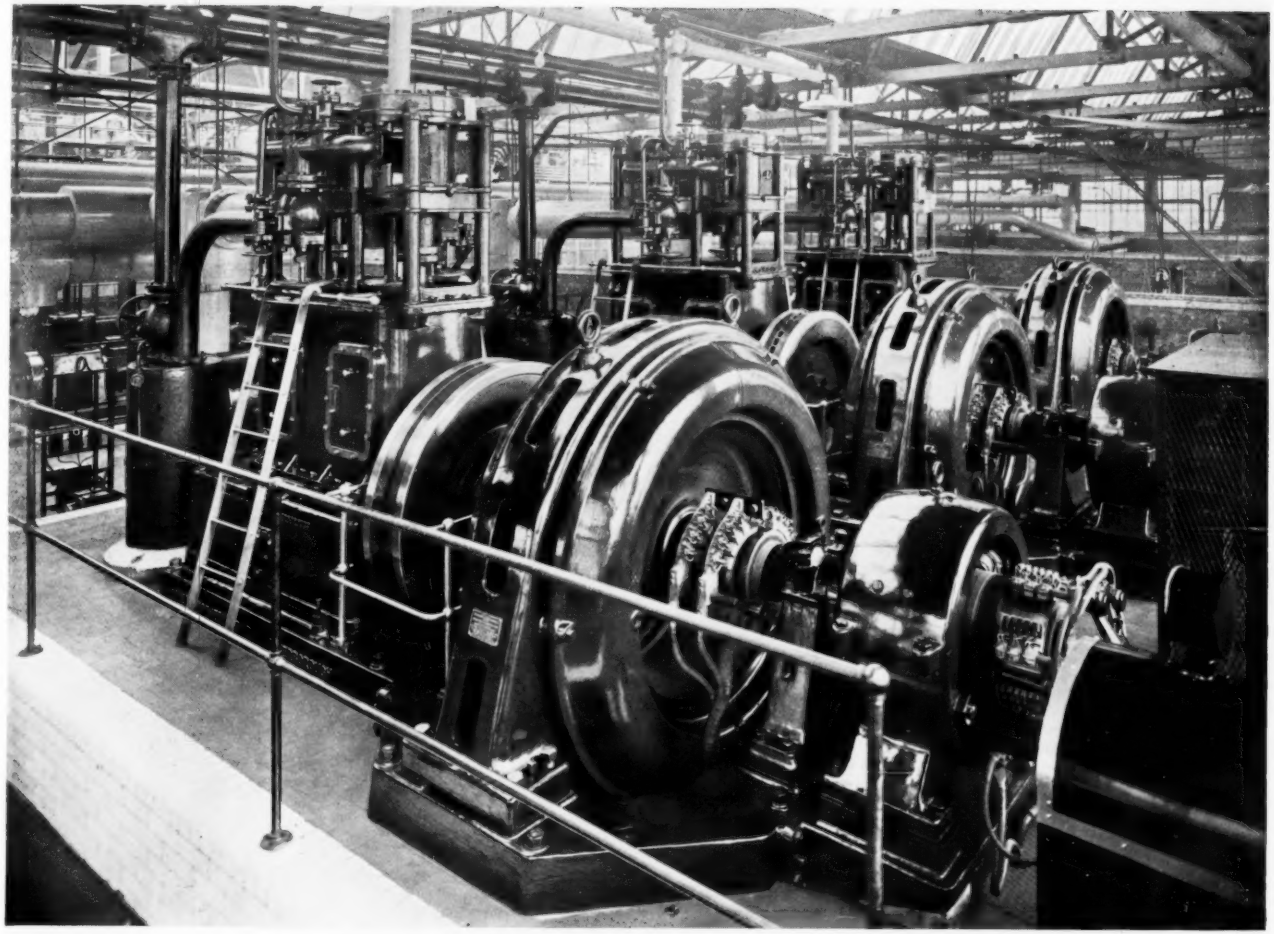

THREE "ENGLISH ELECTRIC" ASYNCHRONOUS-SYNCHRONOUS MOTORS DRIVING COMPRESSORS AT THE CENTRAL REFRIGERATING PLANT OF MESSRS. J. LYONS & CO., LTD.

The English Electric Journal

Vol. III. No. 2 APRIL/JUNE, 1925 One Shilling

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All Communications respecting Editorial Contents should be addressed to THE EDITOR, THE ENGLISH ELECTRIC JOURNAL, QUEEN'S HOUSE, KINGSWAY, LONDON, W.C.2.

EDITORIAL.

The widespread interest in electrical development in this country has for some time disturbed the Gas Companies, and the flutter which it has caused has now become apparent through the speeches of their representatives. The Press has reported at length their protests against what they choose to call an unfair national subsidy, their eulogies of their own product and their depreciations of electricity. The popularity of electricity has been put down to an element of mystery and romance which it is supposed to possess: this, we are told, will fade before the more solid benefits of its rival.

It is indeed hard to believe that not only ordinary householders but the leaders of the industry and Government of the country have been inveigled into their faith in electricity by such false allurements; and the most cursory examination of this latest outcry will show that it is derived not so much from a consideration of the respective merits of these two sources of energy, but from causes that are more nearly allied to self-interest. To take the private house merely as a starting point, strong arguments can be brought to support the use of electricity for domestic purposes—a sphere where it is increasingly popular. But it would be absurdly

inadequate to represent the situation as a rivalry between the gas mantle and the electric lamp or even the gas fire and the electric stove. The chief field for electrical development has always been held to lie in industry and transport. Here the argument whether gas or electricity produces the same results more economically ceases to be worth serious consideration. *Si monumentum quaeris, circumspice:* it is only necessary to turn over the pages of any number of this Journal to find a score of important functions now being performed by electricity for which gas can offer no alternative.

Many of these uses are only possible through the greater mobility of electrical energy, which can be supplied at a distance of many miles from the generating station ; and the leaders of the gas industry have been careful to aim a blow at this vital point of transmission. They contend that the high cost of cables makes the price of electricity prohibitive, especially in rural areas, and so hope to dispose of an argument which would otherwise reduce gas to a sorry opposition. No one would attempt to deny that the question of transmission is one of the most serious in the development of electricity ; but the cause of this should be equally well known. The severe restrictions on overhead lines, which were imposed in the past from a conservative and excessive distrust of a new source of power, are largely responsible for the relatively slow progress which Great Britain compared with some other countries has made in the use of electricity. Times have changed and we can look forward to those greater facilities which alone will bring the supply of cheap, clean, and simple energy to every village and town.

Electricity is not therefore dependent on the enthusiasm of the mob or the puffs of politicians : it can rely on its solid advantages for success. Nor does it need Government subsidies, a mere bogey of its adversaries to terrify the public. But there is every reason why the credit of the nation should be used to foster the growth of electrical enterprises, and in particular the extension of electricity supply through the length and breadth of the land. Schemes such as those which are under consideration by the Electricity Commissioners would absorb skilled labour, and this is a purpose to which the credit of the nation has already and most justifiably been put through the Trade Facilities Act. But to carry these schemes into effect would not be a mere temporary measure for the alleviation of unemployment : it would give definite encouragement to many great industries and help to put them on an equal footing with their rivals in other countries which have long enjoyed the benefits of universal electrification so far denied to us. We venture to hope that no degree of devotion to the therm can now prevent the Government from bringing their electrical proposals to fruition.

The English Electric Company in 1924.

At the Annual Meeting of The English Electric Company, Limited, the Chairman, Sir Charles E. Ellis, G.B.E., K.C.B., in moving the adoption of the report and accounts for the year ended December 31st, 1924, said:—

We meet to-day in the shadow of a great and unexpected loss in the death on Monday of Mr. John Sampson. Before the English Electric Company was formed Mr. Sampson was for many years on the board of Dick, Kerr and Co., and his influence on the development of these and of the other great concerns with which he was associated was as profound as it was unostentatious. A wide knowledge of affairs and a natural breadth of mind made him a symbol of wisdom and stability, and his personal qualities brought him not merely the friendship but the affection of those who worked with him.

The balance-sheet and accounts for the year 1924 are in your hands, and I presume you are already familiar with their main features.

You will notice from the profit and loss account that the net profit of the company for the year amounts to £263,780, a sum slightly in excess of that shown in the previous year. I believe you will see no reason to be dissatisfied with this result, for although trading conditions last year were somewhat better than those of the previous year, the general level of prices still left much to be desired.

You will notice that the 8 per cent. Notes have disappeared and in their place appear 6 per cent. Convertible Debentures. The substantial reduction of £42,321 in Debenture interest charges of the company and its subsidiaries is only one side of the successful financial operation by means of which the 8 per cent. Notes were redeemed. The other aspect is, in my opinion, even more gratifying in that you have emerged from a period of dear money unfettered with any security at a higher rate of interest than 6 per cent. Judging from the steady rise in the price of this 6 per cent. Debenture stock the public have obviously not failed to appreciate the valuable conversion rights which it carries.

In the report of the directors you will have observed, I am sure with satisfaction, that the long and tedious processes which inevitably accompany the liquidation of a large group of subsidiary companies, have, in our case, now come to an end, and I am able to promise you that next year you will receive in one consolidated balance-sheet a statement which will show the assets and liabilities of the entire group as one complete unit.

The year 1924 was one of continued progress in all the branches of the company's business. The volume of orders secured by the company was greater than in any year since its formation. In the home market the failure of successive Governments to carry the essential and vitally important electrical programme past the stage of good intentions caused symptoms of a lull in large-scale electrical development to appear in the latter part of the year. With the agricultural and rural populations of the country less adequately served with electricity than in any of the great countries of Europe any check such as I have described can only be temporary. Indeed, the patience of a great mass of the population of this country in waiting for electricity supply to be made available for them deserves immediate legislative recognition.

Abroad there are few markets in which the company has been unable to find a sale for its products in world competition. The range of those products was made apparent to visitors from all parts of the world in the Company's exhibits at Wembley last year. Whatever complaints may be heard as to the financial aspect of the Exhibition as a whole, we as a firm have no reason to regret the expenditure incurred. Our exhibit, which is fully described

in the issue of *The English Electric Journal* circulated to you with the report, aroused the keen interest and appreciation of Colonial and foreign engineers. To most of them the names and products of Dick Kerr, Willans and Robinson, Siemens, and Phœnix had been familiar for a generation, and the exhibit at Wembley revived earlier associations and furnished convincing proof that old traditions had been continued.

We have confidence that the strong position which we have built up in the export trade can be maintained and strengthened. The absence of any serious trade dispute in the industry during the last three years has been an important factor in our ability to meet foreign competition, and as a company we have had the assistance of all the workers in our employ, who have worked loyally and well at a time when general economic conditions have brought the wage of a skilled craftsman below that of the scavenger in his sheltered trade.

If we turn from these general considerations to particular features of the year's trade we shall find electric traction again in the front of our activities. We completed during the year the electrical equipments ordered by the Great Indian Peninsula Railway for their suburban lines running out of Bombay, and those equipments are now in operation. Good progress was also made with the traction motors, rotary converters, and other material which we are manufacturing for the electrification of the South-Eastern section of the Southern Railway, and before the summer is out most of this material will be in commercial service. During the year we delivered several heavy electric locomotives to the Montreal Harbour Board and others to the Japanese Government Railways. Amongst a large number of new contracts for railway electrification material the most important was that which we received from the South African Railways for the whole of the electrical equipments required for the electrification of their suburban lines in and around Cape Town. When this order is completed the " English Electric " form of camshaft control, which was originated by our own designers and developed in this country, will be in operation in every one of the six continents.

The other departments of our business have kept pace with the electric traction department. We have recently completed or have on order steam turbines and water turbines of the largest sizes, with the electrical generators driven by them, for countries so far apart as Poland, Japan, Australia, India, Canada and South Africa. The Fullagar internal combustion engine, which we have developed for land purposes, is now in commercial service all over the world, and in weight, dimensions, and cost for a given output is recognised to have great advantages over competing types. Of its reliability and efficiency in service there is convincing evidence. In more than one station Fullagar engines installed by the Company have been carrying the bulk of the load from the time of their installation. We received recently a report on the running of one of these engines in the West Indies. Owing to the breakdown of the other plant in the station, the engine went on full load from the first day on which it was put into commission, and ran for 16 hours a day for the next six weeks without a hitch, while the repairs to the old plant were being completed.

The universal development of electrical generating stations, whether steam, water, or oil driven, necessarily brings in its train a growing demand for our standard industrial plant and apparatus. In mines and steelworks, in textile mills and factories of every description, " English Electric " motors are to be found, driving hoists and winders, fans, pumps and compressors, rolling mills, looms, machine tools, lifts and escalators. Over all this range, while the application of electricity is in one sense standardised, it is, in another sense, progressive and fluid, and our efforts are uninterruptedly directed by research and experiment to the improvement of our designs. During the year the research department of our principal works has been much enlarged

and this step will certainly contribute in the future to the reduction of manufacturing costs simultaneously with the attainment of increased reliability, efficiency and adaptability to the changing processes of industrial life. That, you will agree, is a task worthy of a great organisation, and it is also one in which the success of any organisation will oe measured by the sense of a common purpose running through its members.

Another important part of the company's operations to which I wish to refer is what I may call our co-operative activities through The Power and Traction Finance Company. That company exists for the investigation, financing and execution of comprehensive engineering schemes in which civil, mechanical, and electrical work are all involved. During last year it was responsible for the promotion of the Lanarkshire Hydro-Electric Power Act, by which wide statutory powers were obtained for the development of the Falls of the Clyde. In agreement with the Clyde Valley Power Company, in whose area the falls are situated, we are now carrying out, through The Power and Traction Finance Company, extensive hydro-electric works. When they are completed, not only will upwards of 20,000 h.p. which for centuries has been running to waste, be available for the electrical development of the district, but a model hydro-electric installation on a large scale will have been constructed for the first time in this country entirely to British design and by British manufacturers. For the future expansion of the company's water power business we attach the greatest importance to this contract. The principal markets for hydro-electric plant are abroad, and to the purchasing engineers who visit Europe from India or Japan or Brazil, we shall be able to show a complete installation carried out by us here at our doors and comparable to those which we have in operation in other parts of the world. In this way what has hitherto been an important advantage of our Continental competitors, who have vast water power resources developed in their own countries, will be fully counterbalanced.

Another co-operative enterprise in which we are interested is The Sudan Light and Power Company, which has been formed to take over from the Sudan Government the operation of the electricity and water supply and the transport services in Khartoum and Omdurman. Important extensions are being carried out in all these services to meet the needs of the population, and we are confident that the rapid development of the natural resources of the Sudan will ensure the growth and prosperity of the new undertaking.

This brief survey will, I think, indicate to you the nature of the work which is being done by your company. The possibilities of electrical development are so far from being exhausted that we may reasonably look to an extended market for our products throughout the world. The business of the company rests on the solid foundations of technical and manufacturing achievement, and in that lies the surest guarantee of the future.

The New Turbine Design of The English Electric Company.

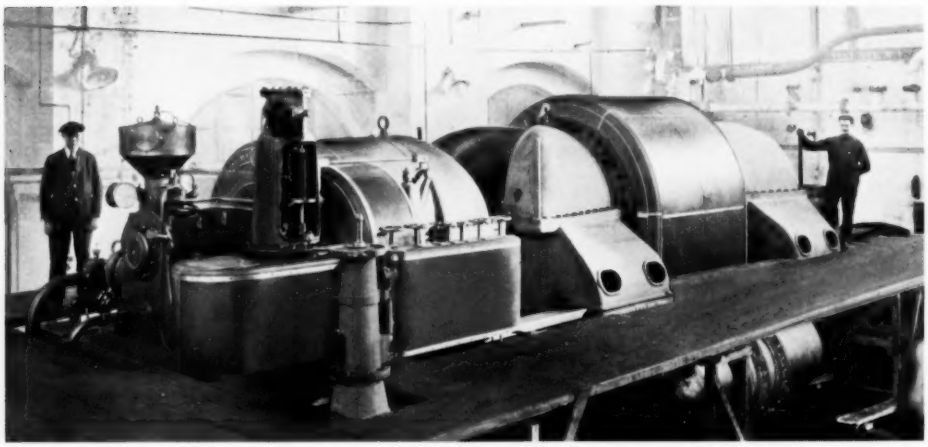

FIG. 1. 20,000 K.W., 3,000 R.P.M. TURBINE ON TEST AT RUGBY WORKS.

The long experience of The English Electric Company in the construction of steam turbines of both the reaction and impulse types, has enabled them to appreciate very thoroughly the special merits and defects of each, and as the Company are equally free to manufacture either type they are in a position to offer their customers the most suitable machine for any given conditions. Both types are now too well known to render any general description of their mechanical features necessary, but in order that the significance of the latest development of the Company's practice may be understood, it will not be out of place to refer briefly to the advantages and otherwise of the respective types. The most obvious advantage of the impulse design is the large clearance which can be given round the running blades; while the relatively robust construction to which the principle lends itself eliminates the danger of distortion and other troubles due to the high temperatures and pressures at which steam is now used. Furthermore, the fact that the steam does not enter the turbine casing or come into contact with the wheels and blades, until after it has been expanded in a nozzle to a much lower temperature and pressure than those existing in the steam chest, is a great practical advantage. Another feature which is often claimed as advantageous, is the possibility in the impulse machine of restricting steam admission to a comparatively short arc of the high-pressure stages. The length of the nozzle arc can be progressively increased from stage to stage until at the low-pressure end the whole circumference is used. Although this practice permits of a uniformly high blade speed throughout the turbine without undue disproportion between the lengths of the high-pressure and low-pressure blading, the seriousness of the losses due to the idle blading is now being more fully recognised, and " partial

admission," as it is called, is admittedly inferior to admission of steam round the whole circumference of all wheels, when the highest possible efficiency is called for.

The tendency in machines of the impulse type has been towards the highest possible blade speeds, with a view to minimising the number of stages required for a given efficiency and so reducing the length and cost of the turbine. Speeds up to about 1,000 ft. per second have been adopted by some builders with this object in mind. Safety under the high centrifugal stresses which these speeds involve can be ensured only by extreme care in design and manufacture, and although we in this country have fortunately been free from such spectacular disasters as have been caused by the bursting of turbine wheels in America, there is always the risk of serious accident due to some unsuspected defect of material. Moreover, with the large outputs and low exhaust pressures for which turbines have now to be designed, the simple impulse type of machine is reaching its limitation on account of the difficulty of providing an adequate area for the steam flow through the later stages. Unless this area can be provided, the steam has to pass to the condenser at an unduly high velocity, with correspondingly large " leaving losses," and much of the economy due to high vacuum is lost.

The reaction turbine, on the other hand, shows to its greatest advantage when dealing with large volumes of steam at comparatively low temperatures and pressures. Under such conditions, the extremely fine clearances at the blade tips necessary to prevent an abnormal leakage of steam from stage to stage become no longer essential, and comfortable clearances may be allowed. With lower temperature of the steam, also, troubles from casing distortion can be avoided, and the inherently higher efficiency of the reaction principle can be obtained without most of the practical drawbacks which attend its use in high-pressure machines. The reaction machine also has certain constructional advantages. The rotor instead of consisting of separate wheels, the cost of which tends to limit the number which can commercially be adopted, is formed as a drum, forged hollow or solid, as the case may be. The surface of the drum affords space for a very large number of stages, and consequently a very high efficiency can be obtained without incurring excessive cost or involving high stresses in the material.

Both the impulse and the reaction types of turbine can, of course, be built in any size yet demanded, and up to the present it has been the practice of all turbine makers to concentrate their attention on the exclusive development of the type with which they were most familiar, and to ignore the fact that the other has in some respects points of superiority. The demand for machines to take the fullest advantage of the very high steam temperatures and pressures which are coming into use, and to utilise equally efficiently the very low condenser pressures which it is now practicable to obtain, led The English Electric Company to make a careful study of the whole problem of the design of large modern units. The limits of existing types appeared to have been reached, and the object of the company was to see whether by co-ordinating the accumulated results of practical experience and studying them in the light of the results of the great amount of research work carried out by their own engineers and others, it would not be possible to produce a type of machine distinctly in advance of current practice.

It is needless to say that, in this endeavour, the question of reliability was never out of mind. The possibility of securing higher economy at the expense of safety in operation was never entertained, for the larger the unit the more imperative it is that there shall be no risk of breakdown. The aim of the Company, indeed, was to improve, if possible, on the standard of reliability already attained by the best machines, and to incorporate in the design, at the same time, every feature of turbine practice which experience or research had shown to be conducive to the highest efficiency.

Modern conditions indicated that machines of from 10,000 to 20,000 kilowatts capacity, running at 3,000 revs. per min., would find a wide field of usefulness. Turbines having outputs of this order are large enough to justify the cost of those refinements of design which are necessary to the utmost efficiency, and yet are not too large for the majority of important power stations. The same principles can, of course, be embodied in the larger units which will be demanded for the super-stations now being contemplated, but commercial considerations naturally indicated the advisability of meeting, in the first place, the requirements of the largest prospective market.

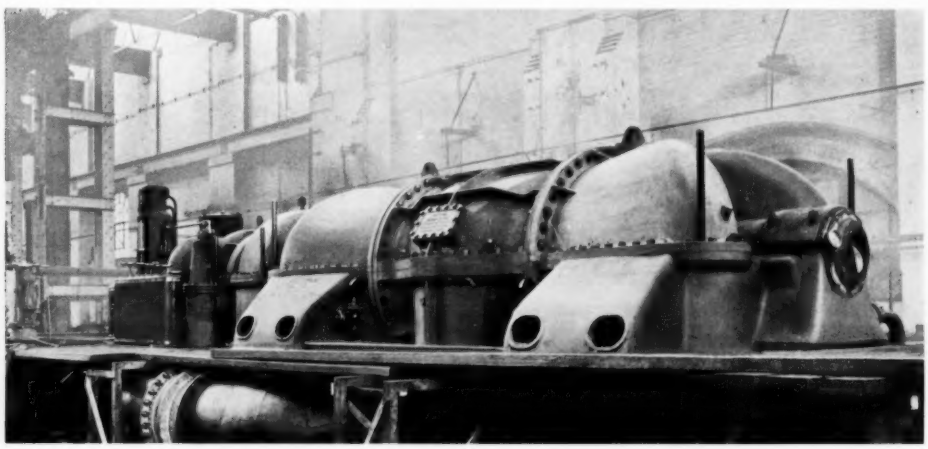

FIG. 2. 20,000 K.W., 3,000 R.P.M. UNIT. LOW-PRESSURE END.

The advantages of the impulse principle for utilising the energy of high-pressure steam, and of the reaction principle for dealing with steam at lower pressures and temperatures, pointed to the desirability of so designing the new turbine as to secure the maximum benefits of each type. This idea could be carried out effectively only by building a turbine with two separate cylinders in tandem, and the following considerations confirmed the view that this was the best course to adopt. In the first place the two cylinder design enabled a speed of 3,000 revs. per minute to be used efficiently even for machines with a capacity of 20,000 kilowatts, a result which could not be obtained with a single cylinder turbine. Again, as the practice of re-heating the steam during the course of its expansion is likely to be adopted extensively in the future, it was naturally desirable to adopt a design which would facilitate the necessary connections when required, and this rendered the choice of a machine with separate high and low pressure cylinders almost imperative. Moreover, the employment of a separate low-pressure reaction cylinder made it easy to utilise the double-flow principle for this part of the unit. This enabled shorter and stronger blading to be employed, avoided the necessity for dummy balancing pistons with the losses and fine clearances they entail, and also simplified the condensing arrangements.

Before coming to a final decision on the question of type, numerous alternative designs were prepared and were thoroughly discussed. The outcome of these deliberations was the adoption of the design shewn in Plate I (facing page 72), the merits of which were so readily appreciated that the Company almost at once received an order for a turbine of the type with a maximum continuous

rating of 20,000 k.w. at 3,000 r.p.m. to be installed in a large power station in the North of England. An inspection of the illustration will show that the machine embodies all the features which we have shown to be advantageous, and that these have been combined with a sound mechanical construction. The high-pressure rotor consists of twelve impulse stages, but the blades are not carried by independent wheels keyed separately to the shaft in accordance with usual practice, but are mounted on wheels integral with the shaft, the whole being turned out of a solid forging. The shaft is drilled through from end to end in order that its absolute soundness may be established by internal inspection. The rotor runs well below its first critical speed, so that it never passes through a vibrating stage when starting or stopping. It is subjected to no appreciable end thrust, but nevertheless is located axially in position by a double thrust block of the Michell type housed in the high-pressure bearing, so that the casing and rotor retain their exact relative positions when expansions or contractions due to temperature changes take place. The high-pressure casing consists of a steel casting extending far enough along the turbine to include the first eight stages, after which the steam is at a low pressure and comparatively cool, so that no distortion troubles can arise. There is complete steam admission round the whole of the wheels, with a consequent reduction in windage losses, but the horizontal joint of the casing is not subject to high-pressure steam, as the upper and lower steam chests are quite separate.

The design of the high-pressure unit, as a whole, deserves careful study. The blade speed is much lower than that commonly adopted in impulse machines, and apart from the reduction of stresses thus brought about, there are two principal consequences. In the first place the wheels are of small diameter, and it is therefore practicable to make them solid with the shaft. This construction is not only much stronger than the use of separate wheels, but the absence of wheel bosses reduces the diameter of the rotor where it passes through the diaphragms, and consequently reduces the steam leakage at these points. Secondly, the low blade speed involves a comparatively large number of stages to utilise efficiently the pressure drop in the high-pressure cylinder. As a result of the larger number of stages, the blade heights can be increased in a much more gradual manner from stage to stage than is usually possible in impulse machines, and more favourable condi-

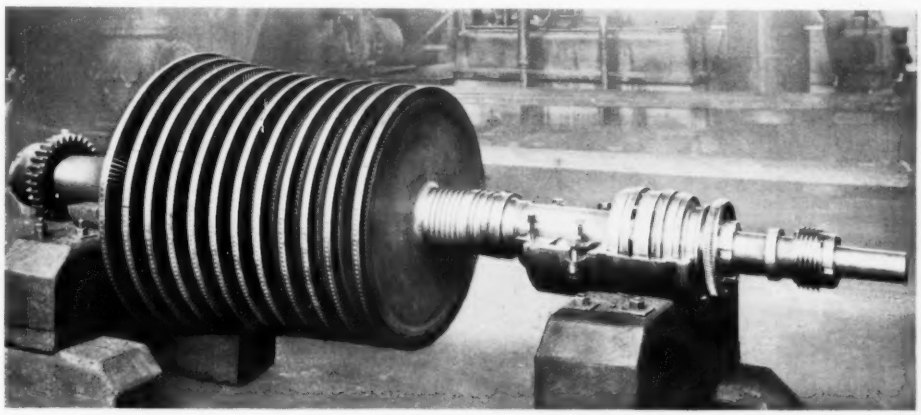

FIG. 3. HIGH-PRESSURE ROTOR OF 20,000 K.W. UNIT.

tions of steam flow are thus obtained. Equally important, however, is the effect of the increased number of stages in diminishing the sharpness of the temperature gradient along the machine. The total temperature difference is spread over twelve stages comprising a considerable length of casing, so that at no point is there any abrupt drop of temperature to cause distortion troubles and heat losses. The length of the rotor is not too great to prevent the critical speed of the machine from being kept well above the running speed, for the wheels are light and the solidity of the construction gives an intrinsic stiffness not obtainable in the usual design.

The low-pressure unit of the complete machine is of the pure reaction or Parsons type. Steam leaving the exhaust end of the

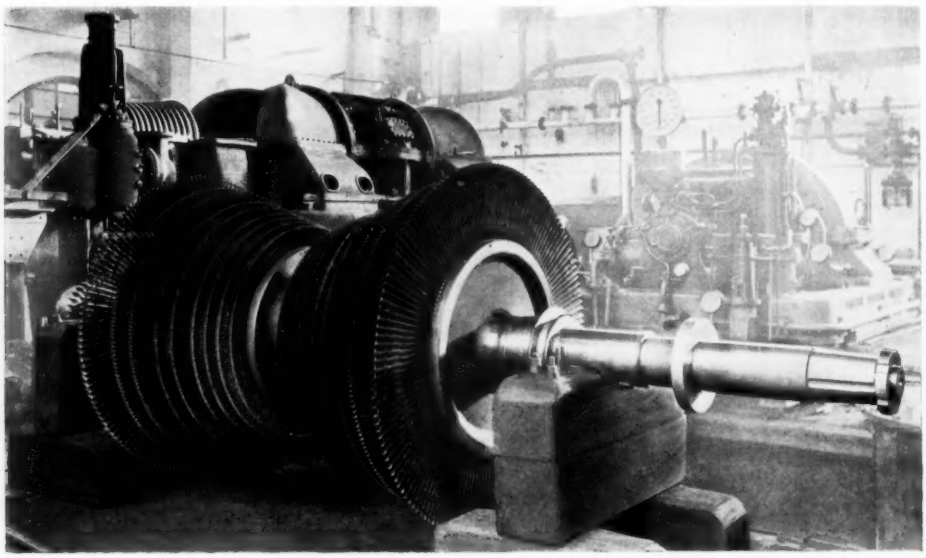

FIG. 4.
LOW PRESSURE ROTOR
OF
20,000 K.W. UNIT.

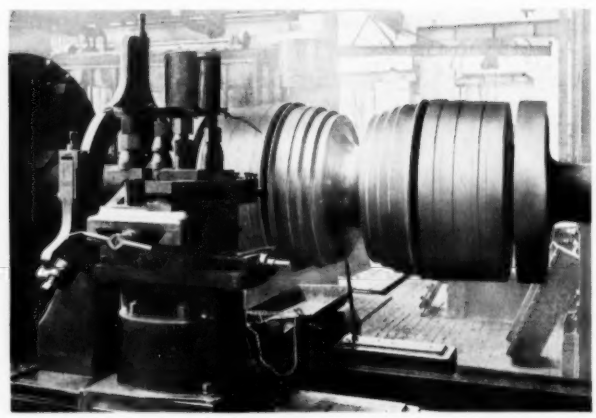

FIG. 5.
TURNING THE DRUM
FOR THE
LOW-PRESSURE ROTOR
SHOWN IN THE PREVIOUS FIGURE.

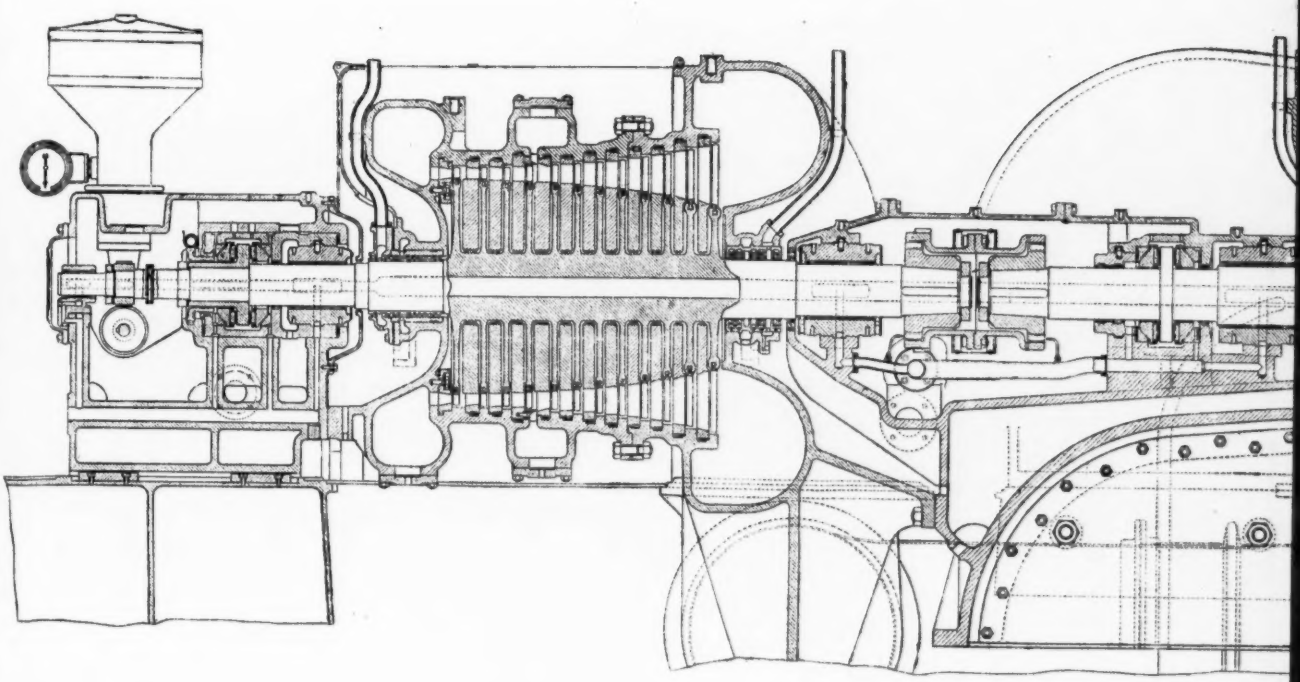

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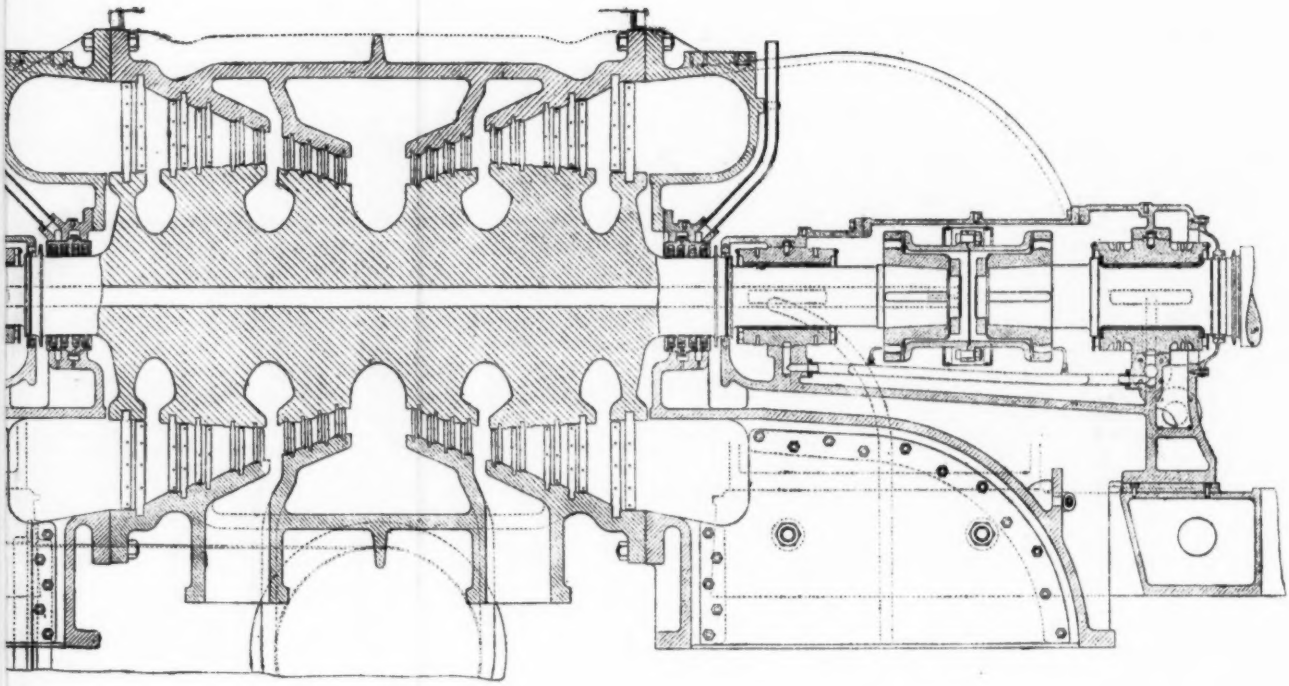
PLATE I.—DIAGRAMMATIC SECTION OF 3,000



R.P.M. Turbine Unit for Large Outputs.

high-pressure unit at atmospheric pressure or thereabouts, is either taken direct to the centre of the low-pressure cylinder, or in instances where reheating is adopted, passes through the reheater on its way. It then flows axially towards both ends of the low-pressure rotor, doing work on the various groups of reaction blading and finally passing away to the exhaust. The low-pressure rotor, like the high pressure one, is composed of a solid steel forging bored from end to end to ensure soundness of material. It, too, runs below its first critical speed and so eliminates vibration troubles. It is in perfect axial steam-balance, and is located in position by a double Michell thrust-block contained in the intermediate pedestal. Flexible couplings of the Company's standard multi-tooth type are used to connect the low-pressure rotor to the high-pressure rotor at one end and to the alternator at the other. The design allows any one of the three rotors to be removed without disturbing either of the others.

The design of the low-pressure casing makes provision for bleeding off steam for feed-water heating, as this practice is now adopted in all modern stations on account of the higher overall thermal efficiency which it allows. It has the further advantage from the turbine builders' point of view that it reduces somewhat the volume of the steam which has to be passed through the final stages of the turbine, where it is difficult to provide an adequate area for the steam flow without unduly increasing the blade heights. The double-flow arrangement, however, greatly reduces this difficulty, and, as will be evident from the drawing, it has been found possible to keep the low-pressure blading to very reasonable proportions, although no sacrifice of efficiency has been entailed. Another advantage of the double-flow design lies in the effect it has on the condensing plant. To condense nearly 200,000 lbs. of steam per hour, which is the quantity passing through a 20,000 kilowatt machine at full load, and to maintain a vacuum in the condenser of over 29 ins. under such conditions calls for a very large condensing plant. If all the steam has to be dealt with by one condenser this must be of such a size that, not only is it difficult to find room for it under the turbine, but to ensure an equal distribution of steam over the whole of the cooling surface is also a somewhat difficult problem. By putting in two smaller condensers having in the aggregate the same amount of cooling surface the head room required is reduced, better condensation can be effected and there is, moreover, the specially valuable feature that one may be temporarily out of service for cleaning or otherwise without putting the whole unit out of commission. The double-flow low-pressure turbine lends itself admirably to such an arrangement, which therefore is generally adopted, and is in accordance with the policy of the duplication of circulating pumps and other auxiliaries, which experience has shown to be so advisable.

The first machine to be constructed by The English Electric Company to their new design is shown in Fig. 1, page 68, as it appeared on the test bed at the Willans Works before despatch. It is designed for a maximum continuous output of 20,000 kilowatts at 3,000 revs. per minute, and the official tests which are to be taken shortly, are confidently expected to show an efficiency which will mark a record for machines of the size in question. Fig. 2 is a view taken from the low-pressure end of the unit before the lagging was put on, and it gives a good idea of the simplicity of the large castings and the stability of the supports by which their weight is transmitted to the foundations, a feature which is essential to quiet and smooth running. Some of the important details of the turbine are illustrated separately in Figs. 3 to 6.

Fig. 3 is a photograph of the high-pressure rotor with its twelve wheels completely bladed and shrouded. At the far end of the shaft will be seen the toothed flange of the flexible coupling which forms the connection to the low-pressure rotor. The near end of the shaft is supported in the lower half

of its own bearing with the double thrust block in position. The fine axial adjustment of this block, and therefore of the rotor, is made by a screwed sleeve which can be rotated by means of a worm engaging in the worm wheel just outside the bearing. The small multiple-thread worm near the end of the shaft drives the governor and oil pumps.

The low-pressure rotor, also completely bladed, is shown in Fig. 4. The blading in this case is unshrouded, but the individual rows are strengthened by numerous concentric rings of lacing wires passing through the blades of each row and welded to them. All blading throughout the turbine is of steel, machined individually from solid bar or strip, highly finished to its exact form and mechanically attached to the rotors. In the background of Fig. 4 can be seen the turbine itself in course of erection, with the high-pressure rotor exposed. Fig. 5 shows the low-pressure rotor in the lathe having the grooves machined to take the blading, and Fig. 6 illustrates the machining of the casing which surrounds the rotor in question. The two halves of the casing, having been bolted together, are having the end-flanges faced in a large vertical boring mill, the size of which is indicated by the man operating it. The two large branches projecting from the casing are the inlets of the steam to the low-pressure turbine, and the smaller ones are outlets for some of the partially expanded steam to pass to the feed water heaters.

The machine we have described marks a decided step in turbine design. The limitation of the impulse principle to the pressure range only where it is particularly advantageous, and the adoption of proportions calculated to give maximum efficiency, have resulted in a high-pressure unit of exceptional merit. The combination of this with the well known advantages of the double-flow reaction principle for the low-pressure unit, has enabled a type of machine to be produced which is capable of meeting the severest requirements of modern power station practice as regards both thermal efficiency and reliability. The favourable reception accorded to the type by central station engineers is shown by the fact that, in addition to the machine referred to in this article, the Company have now on order similar machines, though of somewhat smaller capacity, for the Dundee Corporation and The Charing Cross, West End & City Electricity Supply Company respectively.

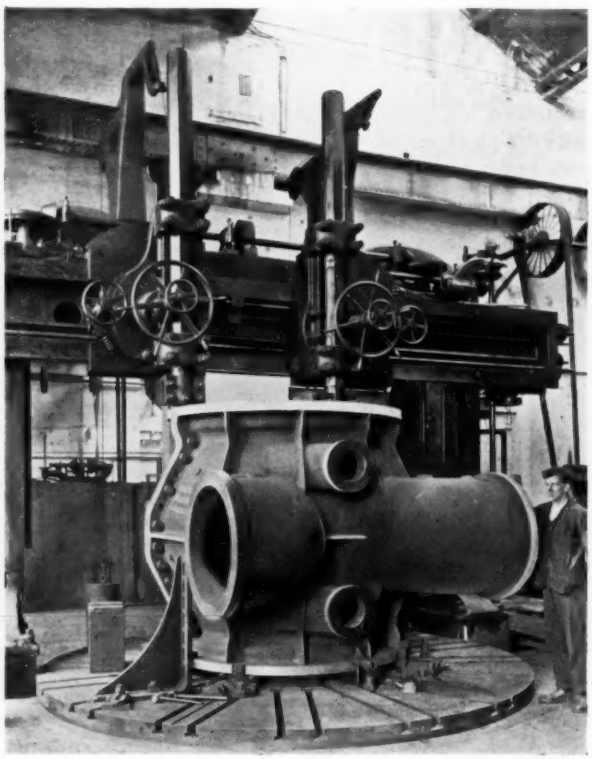


FIG. 6. MACHINING THE LOW-PRESSURE CASING OF A 20,000 K.W. UNIT.

Applications of the "English Electric" Asynchronous-Synchronous Motor.

The rapid spread of the industrial application of alternating current for electric power supply has brought in its train the necessity of some form of machine for relieving the generating plant and supply network of a large amount of the wattless magnetising current required by the transformers and induction motors connected to the system.

Amongst the machines developed for this purpose, none has a wider field of application than the specially designed induction motor equipped with a D.C. exciter, by means of which its field system is excited and the machine brought into synchronism after attaining speed as an induction motor. Such machines have attracted considerable attention, as is demonstrated by the large amount of literature and discussion which has been devoted to the subject in this country, the U.S.A., and on the Continent of Europe.

The English Electric Company have had a particularly wide experience in the design and application of these motors, and have supplied an aggregate of many thousands of H.P. covering a variety of drives, some of which will be described.

It may be taken as an axiom that the most suitable motors with which to supply leading wattless current for the correction of power factor are motors which are continuously running on a fairly steady load. In colliery work the best example of such an application is the

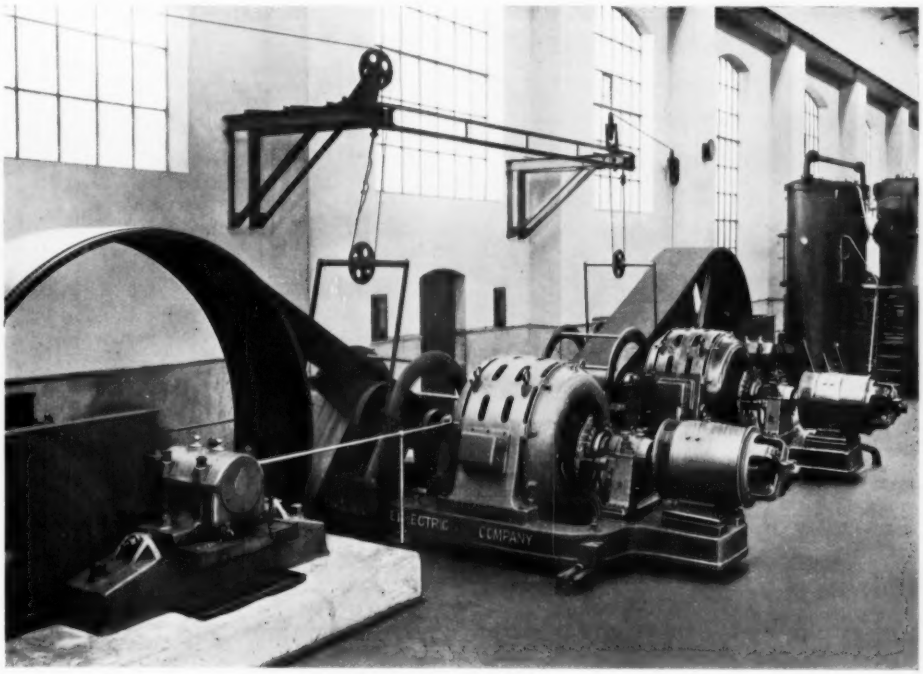


FIG. 1. 450 H.P. ASYNCHRONOUS-SYNCHRONOUS MOTORS DRIVING COLLIERY FANS.

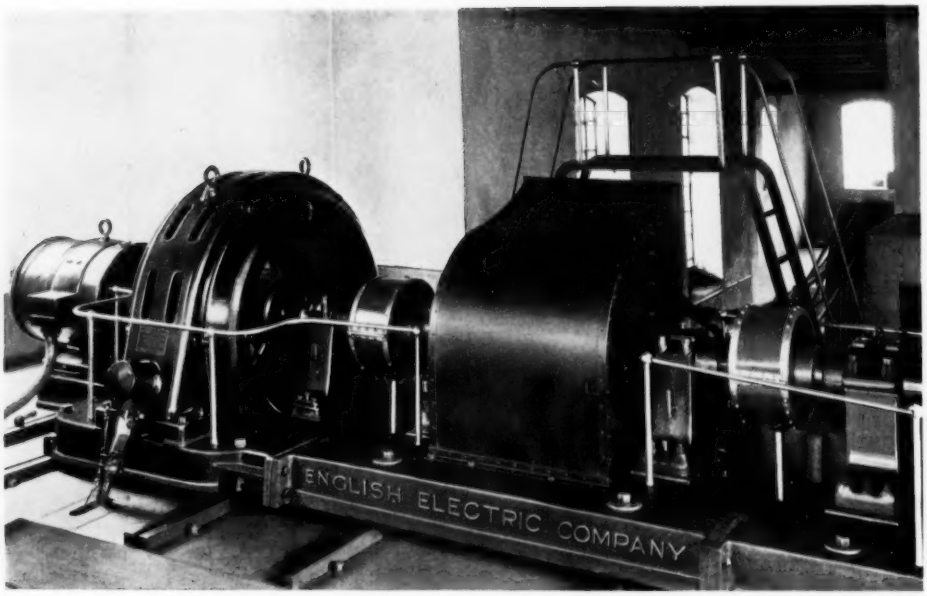


FIG. 2. 375 H.P., 3-PHASE, 50-CYCLE, 300 R.P.M. ASYNCHRONOUS-SYNCHRONOUS MOTOR DRIVING COLLIERY FAN THROUGH ROPES.

driving of ventilating fans. Fig. 1 shows a typical drive of this nature, and illustrates two 450 H.P. 3-phase 50-cycle 3150-volt motors, running at 750 r.p.m., and driving colliery fans by belt through Lenix belt-tensioning gear. Eight such equipments of 450 to 575 B.H.P. output have been supplied to one colliery company alone. The motors operate with a leading power factor of ·80, which represents 2400 KVA. wattless current supplied to the line for power factor correction and relief of the generating plant. The average full load efficiency is 93 per cent. when operating at ·80 leading power factor, and over 94 per cent. if operating at Unity power factor.

Fig. 2 shows another colliery fan drive, but in this case by means of ropes. This motor has an output of 375 H.P. at ·80 leading power factor and runs at 300 r.p.m. on a 3-phase 50-cycle 3300-volt circuit.

Colliery fan drive is an interesting application of Synchronous Motor drive on account of the very heavy masses to be accelerated and pulled into synchronism. The previous designs of synchronous motor with a squirrel-cage starting winding embedded in the pole tips were not able to undertake such a heavy duty. If the starting winding resistance was made sufficiently high to move the heavy fan runner from rest against static friction, then the slip was too high for the available synchronising torque to pull the motor into step against the enormous inertia of the fan, during one half slip cycle. On the other hand, if the slip was made small enough to allow pulling into step, the motor could not move the fan from rest. The Asynchronous-Synchronous type of motor has the combined properties of very high starting torque, small slip, and enormous synchronising torque.

A second class of application to which the Asynchronous-Synchronous motor is particularly adapted is the driving of compressors. Fig. 3 shows a large air compressor installed

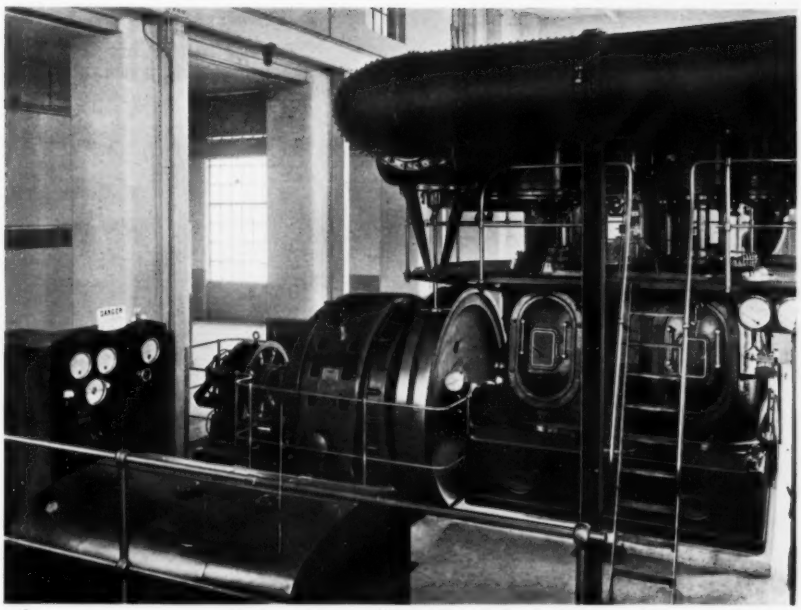


FIG. 3. 1170 H.P. MOTOR DRIVING COLLIERY COMPRESSOR.

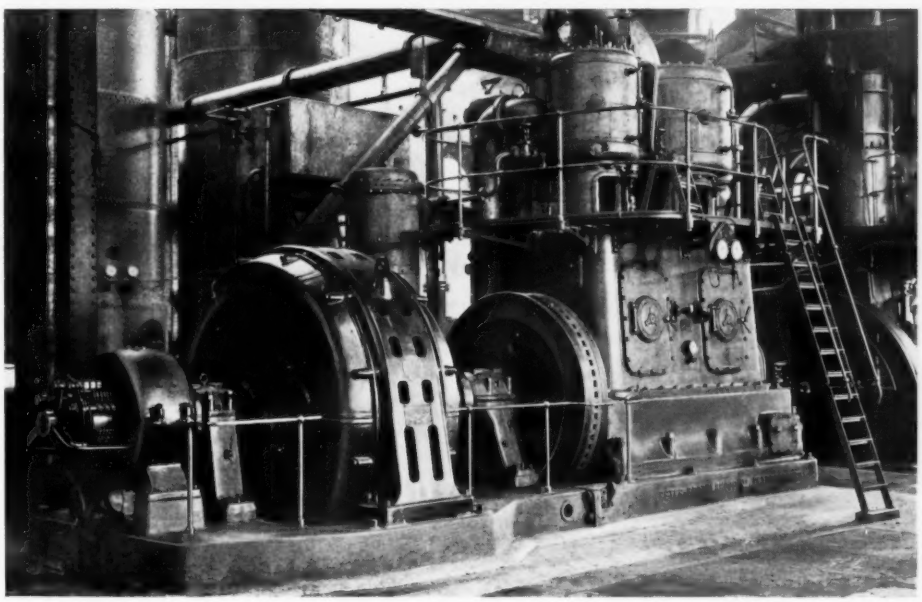


FIG. 4. 800 H.P. MOTOR DRIVING DOCKYARD COMPRESSOR.

in a colliery and driven by a 1170 H.P. Motor running at 218 r.p.m. on a 3-phase 40-cycle 5500-volt circuit. This machine operates with a leading power factor of ·90, which represents 450 KVA. leading wattless supplied to the line for power factor correction. The overall efficiency of this motor at full load is 92·5 per cent., which is fully equal to that of an induction motor of the same speed and output.

Fig. 4 shows a Dockyard Compressor and motor of 800 H.P. at 250 r.p.m. on a 3-phase 50-cycle 6600-volt circuit. This motor is built for Unity power factor, but it must be remembered that this output added to another 800 H.P. of miscellaneous workshop motors having an average power factor of ·70 would mean an aggregate load of 1600 B.H.P. at ·90 power factor, which is a satisfactory improvement.

The Frontispiece shows a battery of Refrigerating Compressors driven by Asynchronous-Synchronous motors of 170 H.P. at 187 r.p.m., 3-phase, 50-cycles, 415-volts, Unity power factor. Five of these motors have been supplied to one firm. Induction motors direct-coupled to these slow-speed compressors would have been larger than the synchronous motors, would have been inferior in efficiency and had a power factor under ·70. This would have meant over 1000 KVA. supply instead of 700 KW. at Unity power factor, and cables for 1500 amperes instead of 1000 amperes. The saving in feeders, cables and switchgear due to the reduced current is very apparent.

The English Electric Company have also supplied Asynchronous-Synchronous motors for the driving of pumps, both high-speed high lift pumps, and low lift pumps up to 1200 H.P. at 231 r.p.m.

It is sometimes desirable to incorporate automatic starting and stopping in connection with pump and compressor motors, by means of pressure relays or floats. Also remote control by means of push button is sometimes required. Asynchronous-Synchronous motors both for pump and compressor drive have been supplied with contactor gear starters for these purposes, and are particularly suitable as there is no change in the high-tension stator connections, and synchronising is so simple and sure that it is easily made automatic. No lamps or synchronoscopes are required.

Other applications include Cotton Mill drives, Flour Mills, Coal Washeries, and Rolling Mill (cold rolling) drives. These motors are suitable for most industrial drives, and particularly advantageous where both power factor correction and high starting torque are required.

Consideration will next be given to the comparative cost and saving to be effected by the adoption of Asynchronous-Synchronous motors for power factor correction.

A recent contract involved the transmission of 3000 KVA., 3-phase, 2200-volts for a distance of 2,000 feet between the power house and the motor load. A portion of this load, amounting to 600 H.P. was suitable for synchronous motor operation, and by installing Asynchronous-Synchronous motors of ·90 leading power factor a saving of 450 KVA. to be transmitted was accomplished.

Saving on cost of transmission line	£400
Saving on cost of generators @ £1 per KVA.	450
	£850
Extra cost of Asynchronous-Synchronous over Induction Motor	300
Saving in capital cost	£550

This is one instance of actual saving in capital cost. The total saving effected by the inclusion of power factor correcting apparatus would be greater because there would have to be taken into account saving in interest and depreciation on the reduced capital outlay, and saving in power bill due to smaller transmission losses and more efficient operation of generators.

In many instances, particularly where electrical power is obtained from a public supply

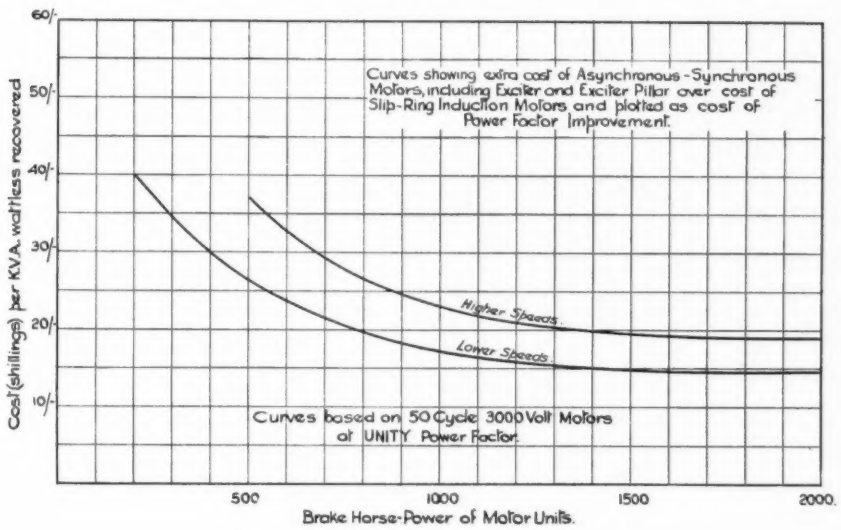

Curves showing extra cost of Asynchronous-Synchronous Motors, including Exciter and Exciter Pillar over cost of Slip-Ring Induction Motors and plotted as cost of Power Factor Improvement.
Higher Speeds.
Lower Speeds.
Curves based on 50 Cycle 3000 Volt Motors at UNITY Power Factor.
Cost (shillings) per KVA. wattless recovered
60/-
50/-
40/-
30/-
20/-
10/-
500
1000
1500
2000.
Brake Horse-Power of Motor Units.

FIG. 5.

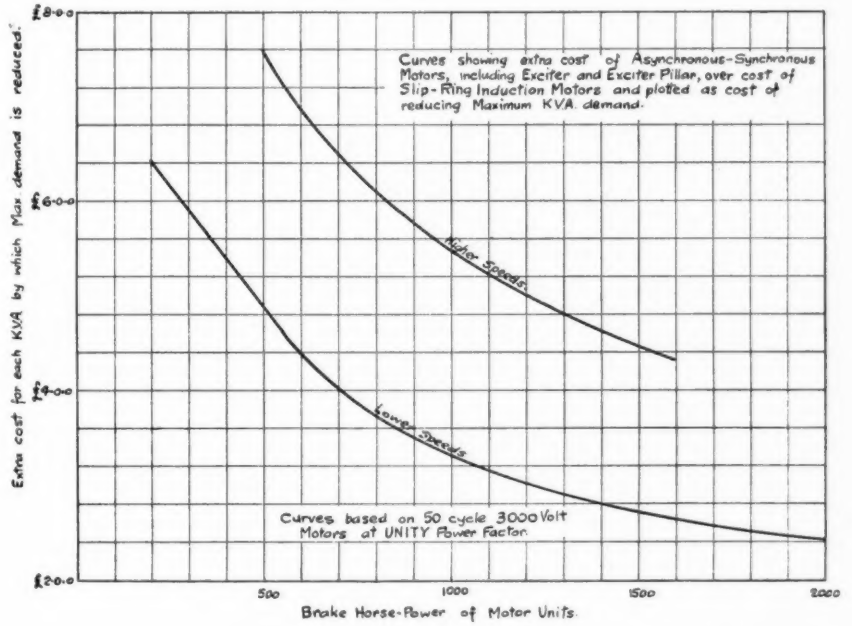

Curves showing extra cost of Asynchronous-Synchronous Motors, including Exciter and Exciter Pillar, over cost of Slip-Ring Induction Motors and plotted as cost of reducing Maximum KVA. demand.
Higher Speeds.
Lower Speeds.
Curves based on 50 cycle 3000 Volt Motors at UNITY Power Factor.
Extra cost for each KVA by which Max demand is reduced.
£8-0-0
£6-0-0
£4-0-0
£2-0-0
500
1000
1500
2000
Brake Horse-Power of Motor Units.

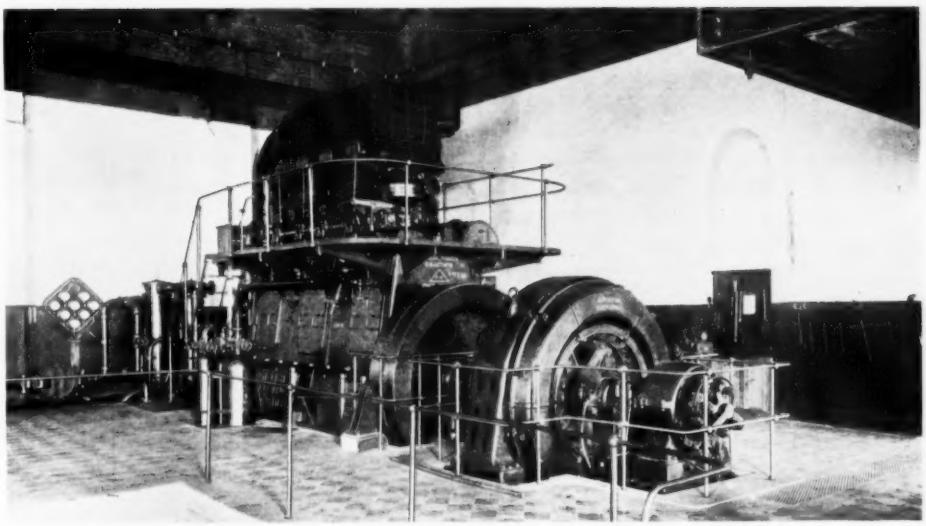
FIG. 6.

authority, the extra cost of Asynchronous-Synchronous motors is justified. Some power authorities stipulate a minimum power factor on their mains with, or without, a rebate for higher power factors. In such cases it may often become compulsory to instal devices for power factor improvement. Several methods may be adopted, but the curves reproduced in Fig. 5 show the extremely favourable costs of Asynchronous-Synchronous motors for this purpose. The curves are based on average figures for Unity power factor Asynchronous-Synchronous motors and represent the extra cost of these motors (above the cost of an equivalent slipring motor) for each KVA. of wattless which would be taken by the induction motor. From these curves a comparison can be made with other forms of power factor correcting apparatus to accomplish the same purpose. The adoption of Asynchronous-Synchronous motors is frequently accompanied by improved efficiency, whereas the use of apparatus external to the motor involves additional losses, and consequently leads to reduced efficiency.

In numerous other cases, and this system of charging for power is growing rapidly, the electrical power companies charge a fixed sum per annum for each KVA. maximum demand, plus a flat rate per kilowatt-hour used. The first portion of this charge is to cover the interest on capital outlay, and is therefore a charge on the maximum KVA. of plant held in reserve for the power user. The flat rate per unit is a charge on running expenses. The maximum demand charge varies from £4 to £10 per KVA. per annum in different localities.

It is therefore to the advantage of customers to take their power supply with as small a KVA. demand as possible, which means as near to Unity power factor as is economical. Fig. 6 shows curves of approximate extra cost for each KVA. by which the maximum demand is reduced by the application of Asynchronous-Synchronous motors. It will be seen that in most cases the extra capital cost is wiped out in less than one year by the difference in the power bill. Even in unfavourable cases the extra cost has been wiped out in less than two years, showing a return on invested capital of over 50 per cent. The most favourable cases are where a comparatively large Asynchronous-Synchronous motor can be used at leading power factor to improve the aggregate power factor of a large number of small under-loaded motors. In this connection it may be observed that the cost of power factor improvement by the use of these motors diminishes as the size of motor increases, and more economical results are therefore obtained by the use of one or two large motors in preference to a greater number of small machines.

"English Electric" Fullagar Engines in Operation.



750 B.H.P. FULLAGAR ENGINE DRIVING ALTERNATOR IN THE KHARTOUM POWER STATION.

A few years ago, after much investigation, The English Electric Company decided to take up the manufacture of large internal combustion engines constructed in accordance with the Fullagar patents. The Company's Willans Works at Rugby previously had many years' experience in the manufacture of Diesel Engines and recognised that the Diesel Engine had a limitation as regards size of unit beyond which it was not desirable to go.

The Fullagar Engine as manufactured by the Company has been described in previous issues of this Journal, and we think that the novel features of the design are well known to our readers. Therefore, in this article we do not propose to go over this ground again, but as a number of engines have already been manufactured and there are several in operation in this country and also abroad, we think it will be of interest to make reference to these machines and to their behaviour when in commercial operation on site.

It may be said at once that the experience with the machines in operation has been eminently satisfactory, and for a new manufacture embodying so many fresh features the results obtained have been unusually successful. These excellent results are, doubtless, due not only to the good features of the Fullagar design as such, but in no less degree to the great experience that our Rugby Works have had in the manufacture of internal combustion engines in the past. The Works have also for years been accustomed to the high degree of accuracy of manufacture which is necessary for the successful manufacture of high-speed steam engines and large steam turbines.

Before the Fullagar Engine was put on the market, not only were preliminary tests and investigations made, but when these were com-

pleted, an engine unit of a large industrial size was manufactured and installed in our own Works in order that complete experience on a commercial scale should be obtained before orders were taken from outside sources. This engine was of 750 B.H.P. rating at a speed of 250 R.P.M., and it has now been in regular service since the beginning of 1922, and has proved to be thoroughly reliable and economical Towards the end of 1923, that is to say, after nearly two years' service, a continuous full load test of 23 days' duration was carried out, followed by a 24 hour test on 10 per cent. overload. The results of these tests were in every way satisfactory. So complete, in fact, was our confidence in the machine that we put in hand a second engine of the same size, and the main power supply for our Rugby Works is now dependent on these two machines. The power supply to a manufacturing works is the most important item in its equipment, and the fact that our Works' Management decided to adopt these engines for their own supply indicates the confidence they have in this type of plant.

It was not until we had had eighteen months' running experience with the engine in our own Works that we began seriously to offer the engine for sale in the open market. As soon as we did so we found that Engineers of experience in this country and abroad at once took a practical interest in the engine, and many orders were secured. For the short time that the engine has been on the market, the results are really remarkable and show that the engine meets a very real demand, and we think there is no question but that it has an unusually successful future before it.

In the next column is a list of the engines in commission and in course of manufacture at the present date.

Regarding the engines in commission we would make the following remarks, commencing with that installed to the order of the Worthing Corporation, as the Worthing Station is one of the largest Oil Engine Stations in the country, its equipment comprising four-cycle Diesel Engines aggregating 1,775 B.H.P. in units ranging from 200 to 500 B.H.P.

The Borough Electrical Engineer, Mr. Geoffrey Porter, who has a very wide knowledge of oil engines, and whose opinion on oil engine matters is highly valued amongst oil engine users, was of opinion that for the output required for their last extension, i.e., 1125 B.H.P., the 4-cycle type Diesel engine was too cumbersome, and after he had made a thorough inspection of the Fullagar engine, and other types, he recommended his Council to instal an 1125 B.H.P. " English Electric " Fullagar Set. The engine has now been in commission since the beginning of last winter, with very satisfactory results.

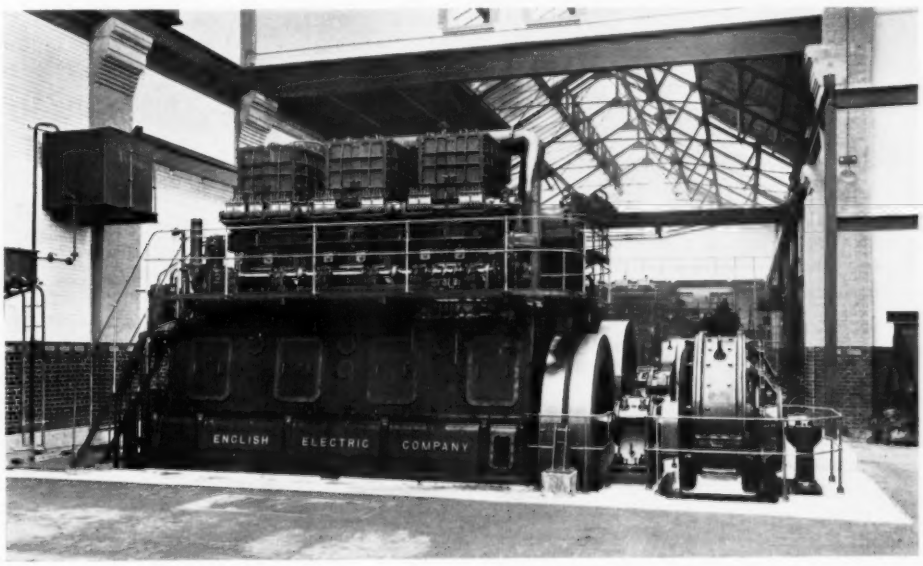
B.H.P.	Customer.	Number.	Remarks.
1125	Worthing Corporation ...	One	In commission
,,	Bermuda Electric Light, Power & Traction Co.	One	,, ,,
,,	Hyogo Electric Railway, Japan	One	—
,,	Sudan Government, Khartoum	One	Repeat Order
750	English Electric Company's Rugby works	One	In commission
	Ditto. ditto.	One	,, ,,
,,	Clacton U.D.C.	One	,, ,,
,,	Sudan Government, Khartoum	One	,, ,,
,,	Birkdale District Electric Supply Co.	One	,, ,,
,,	War Office	One	—
,,	Napier Borough Council, New Zealand	One	—
,,	Lobitos Oil Fields, Peru ...	Two	—
,,	Indian Stores Dept. (Delhi) For Lloyd Barrage Works, Sukkur (Sind)	Two	—
,,	Leatherhead District Electricity Co. (per Messrs. Handcock & Dykes) ...	One	—

As regards the plant for the Clacton U.D.C., the engine was set to work in the middle of September, 1924, and figures obtained at official trials on site show that the actual fuel consumption per kilowatt hour is 0.604 lbs., or 2¼ per cent. below our net guaranteed figure. Further, it is gratifying to note that after the engine has been in operation for seven months the Engineer, Mr. Broadhurst, has expressed his complete satisfaction with its

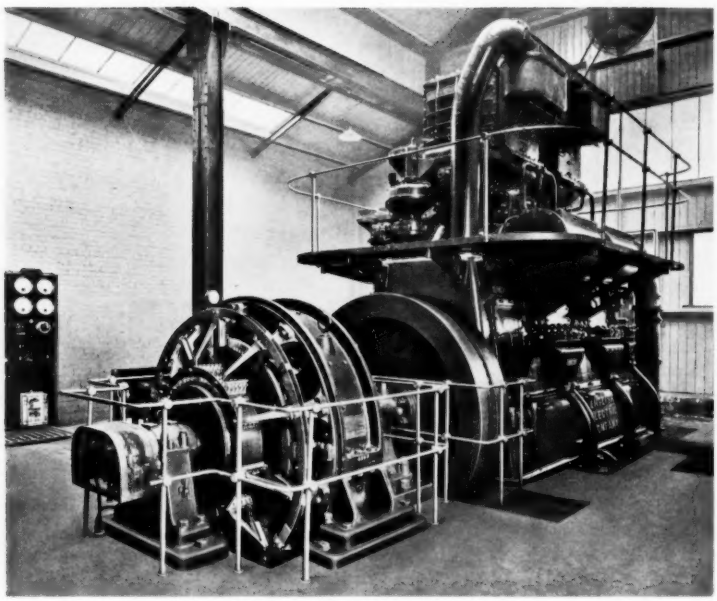
operation and reliability, and has also stated that it requires less attention than the standard type of four-cycle Diesel engine.

The engine supplied to the Birkdale District Electric Co. was put into commercial service early in November last, since when it has been in operation on an average for 16 hours a day.

The confidence we had gained in the Fullagar engine was such that we had no hesitation in accepting orders from abroad, and as regards these foreign machines the one supplied to the Bermuda Electric Light, Power & Traction Co. presents points of particular interest as the conditions at the commencement of running on site were unusually exacting, owing to the urgent demands for power that were made on the Station, and the necessity for putting the engine into commission straight away without any opportunities for preliminary adjustments. The engine met these emergency conditions with complete success; the following particulars which are taken from the record kept at the time show the extreme rapidity with which the set was put into continuous service. The engine was first started up on January 15th at 11.30 p.m., and after a short run at no-load was shut down at 11.55 and the crankcase doors of the engine were then removed and all the reciprocating parts were examined and found to be quite cool. On the following morning, January 16th, the plant was again started up and the engine put on load in parallel with one of the existing oil engines, the output from the Fullagar set being 340 kw. After running for a period of about two hours the engine was shut down for examination and everything was found to be in a satisfactory condition. The plant was then re-started and at once put into full commission with the maximum load of 620 kw., and the engine continued to run on 37 consecutive days for a total period of 528 hours at an average of two-thirds load. No trouble whatever was experienced, and during this run observations were made and a log kept of the various gauge pressures, temperatures, etc. A series of fuel consumption tests were also taken on the engine, the average figure at 3/4 load being 0.632 lbs. per kw. hour, which is nearly 2 per cent. below guarantee.



1125 B.H.P. ENGINE DRIVING D.C. GENERATOR IN THE POWER STATION OF THE WORTHING CORPORATION.



750 B.H.P. Engine and D.C. Generator at the Works of the Birkdale District Electric Supply Co.

Concerning the engine supplied to the Sudan Government at Khartoum, we have received very satisfactory reports.

The engine has been in continuous operation day and night practically since it was put into commercial operation at the end of January, and at one period was in continuous operation for 21 days before shutting down. After this run an examination was made, and everything being found to be in order, the engine was again set to work under continuous operating conditions.

The conditions under which this engine operates are severe owing to high engine room temperature, and the fact that it has given satisfaction is reflected in a repeat order for an 1125 B.H.P. Engine which we now have in hand.

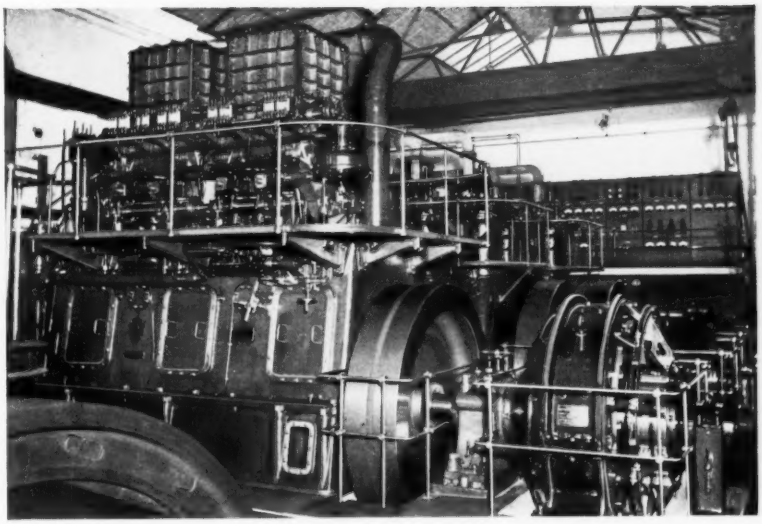
As has been said, the Fullagar engine as manufactured in our Rugby Works has been an unusually successful development, and the advantages offered by this type of machine are such that its use must be greatly extended in the future. We think there is no doubt but that it is the best solution of the large internal combustion engine problem, and provides units of sizes larger than can be satisfactorily supplied of the ordinary Diesel engine type. The engine is less expensive than the 4-cycle Diesel engine; it is efficient, light in weight, compact and of comparatively small dimensions, and provides a unit of large power which can be started up from cold and run up to speed ready for the application of load within 15 to 20 seconds. This feature, combined with the fact that there are no standby losses, makes the engine particularly suitable for Central Station use, and for the driving of storm water pumps; in both of which cases the necessity for quick starting is of vital importance. It remains, of course, true that the engine has great application in any case where a power unit is required, but this feature of extremely quick starting gives it an outstanding advantage in the wide fields of application referred to.

It may not be out of place to recapitulate shortly a few of the special features of the engine, which are additional to the power of extra rapid starting which has been referred to above.

(1) CONSERVATIVE RATING.—Owing to the low mean pressure adopted, the engine is conservatively rated, and its ability to run for

long periods was proved by the 23 days continuous test which we made on our original Shop engine.

Another important advantage of a low-rated engine is that where it is to operate at a high altitude the reduction in output due to the rarefied atmosphere is not nearly so great as it would be in the case of a highly rated engine.



750 B.H.P. FULLAGAR ENGINE AND D.C. GENERATOR IN THE ELECTRICITY WORKS OF THE CLACTON U.D.C.

(2) SIMPLICITY. As there are no cylinder covers, exhaust or air inlet valves, the cost of maintenance is lower, and less attention is required than in the 4-stroke Diesel engine. In the case of the latter engine, it is good practice as a matter of ordinary routine to withdraw and grind in the exhaust valves every 300 to 400 hours, and our experience shows that in the case of the Fullagar engine the pistons, which act as air inlet and exhaust valves, need only be withdrawn for cleaning purposes at intervals of about 2,000 hours.

(3) LOW WEIGHT AND SMALL SPACE OCCUPIED. The weight of the Fullagar engine is about 30 to 35 per cent. less than that of a 4-cycle engine, whilst the individual weights of parts to be handled are also considerably less, the advantage of which will be apparent where an engine is destined for a site where the facilities for handling and transport are not good.

In the case of an order for a Fullagar set which was placed with us some time ago, the specification called for a new overhead travelling crane, but we were able to satisfy the Customer that if our engine was adopted, the parts could be handled by their existing crane, with the result that we obtained an advantage in price due to the omission of the crane which our competitors would have had to provide in order to handle their plant.

Again, as the space occupied by an 1125 B.H.P. Fullagar engine is no more than that required by a 500 B.H.P. 4-cycle Diesel engine, it will be appreciated that foundations and buildings for the Fullagar will be cheaper than for other types of engines.

Other advantages are:—

Good balance and uniformity of torque.

Low piston speed and high rotative speed.

Small load on bearings and low stresses in frame.

Lubrication facilitated by reversal of bearing thrust.

Best scavenge system. There are no separate scavenge pumps or blowers, as the upper crossheads act as displacers for scavenging.

SCHEDULE OF MANUFACTURES OF THE ENGLISH ELECTRIC COMPANY.

Electric Generating Plant of all capacities.
Steam Turbines and Condensers. Turbo-Blowers.
Water Turbines. Internal Combustion Engines.
Rotary Converters. Static Transformers. Phase Advancers.
Switchgear and Controlling Apparatus of all kinds.
Electric Locomotives.
Electrical Equipment and Rolling Stock for Railways and Tramways.
Electric Plant for Rolling Mills, Iron, Steel, Copper Works, etc.
Electric Winding Equipments for Mines.
Electric Equipment for Textile Mills. Standard Industrial Motors.
High-Speed Twist Drills, Milling Cutters and Reamers.
Pneumatic Hammers and Drilling Machines.
Flying Boats.

MOTOR-COACH TRAIN WITH "ENGLISH ELECTRIC" 1200-VOLT EQUIPMENT ON THE OME RAILWAY, JAPAN.

"English Electric" Equipments for Electric Road Transport.

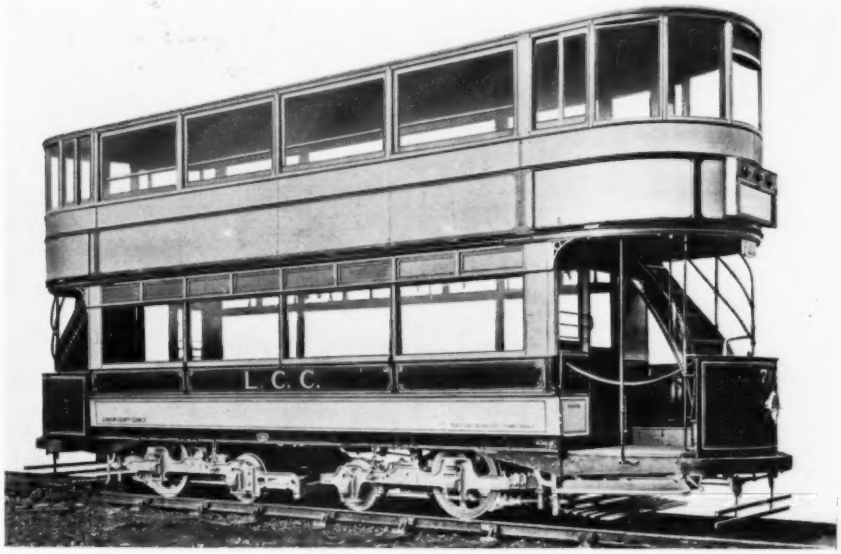


FIG. 1. TYPICAL L.C.C. TRAMCAR FITTED WITH "ENGLISH ELECTRIC" EQUIPMENT.

The pages of this Journal have not hitherto contained much information on the subject of Electric Tramways, and it is hoped that the present article will serve to remind our readers of the important position which The English Electric Company holds in this field. One of its component companies, Messrs. Dick, Kerr & Co., was very intimately connected with the development of electric tramways from the earliest days, and Dick-Kerr Tramway Motors, Controllers and Equipment generally, have always been looked upon as representing the highest standards and latest designs of this class of apparatus. Their equipments have been supplied throughout the world, including Australia, New Zealand, South America, Canada, South Africa, Egypt, Japan, China, Burmah, Ceylon, India, Russia, Greece, France, Holland, Spain and Italy; while at home, they will be found running on most of the tramway systems throughout the country.

At the present time, controversy is active—if spasmodic and sometimes uninformed—as to the relative merits of street tramcars and other forms of urban and interurban passenger transport. Although it would be out of place here to develop a discussion of that question, we think that the particulars given in the succeeding pages will show that The English Electric Company pursues a progressive policy, not only in relation to the development of new designs to meet the changing conditions under which tramways must operate, but also that it has taken a prominent part in the development of an alternative method of electric road transport.

Before passing to a detailed description of some of our current designs, it may be of

interest to link these with the past by recalling one or two of the more outstanding landmarks in the evolution of electric traction equipments. As the first of these we may take the supersession of the totally-enclosed design of motor by a machine having ventilating openings and a properly designed system of definite cooling. This improvement in conjunction with the more skilled utilisation of the materials in the electric and magnetic circuits, has enabled an extraordinary reduction to be made in the weight of traction motors per H.P. developed, and the ventilated type is now almost universal.

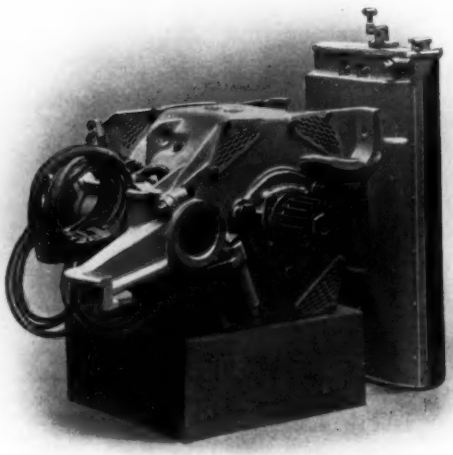


FIG. 2. 63 H.P. MOTOR AND CAM-OPERATED CONTROLLER FOR L.C.C. TRAMCARS.

Another invention which proved remarkably successful, and has stood the test of time very completely, is that of the magnetic-shield blow-out, as applied to controllers and circuit-breakers. This design, which will be well-known to our technical readers, combines an extremely efficient method of severing the arc which occurs on breaking any electric circuit, with a very strong and durable mechanical design. The magnetic-shield blow-out remains a standard design at the present day and has found extended use for switchboard apparatus.

In recent times, The English Electric Company has designed a system of all-electric camshaft-operated control for locomotives and motor coach stock on electric railways, and this has proved most successful on the many systems to which it has been applied, for all conditions of passenger and freight service. As will be seen from the following detailed description, the camshaft principle has now been extended to tramcar controllers, and a large number of these are now in operation.

For convenience, the subject is dealt with under three heads, namely, Tramcar Electrical Equipments, Bodies and Trucks, and Railless Vehicle Equipments.

TRAMCAR ELECTRICAL EQUIPMENTS.

We have recently made certain marked developments in tramcar electrical equipments in order that tramway transport authorities might combat the increasing petrol 'bus competition. A faster service has been called for on this account, and as the free running speed of tramcars is limited by the Ministry of Transport regulation, tramcar motors capable of developing a higher acceleration in order to increase the scheduled speed of the service have been designed and manufactured by this Company.

The largest tramway motor in use in this country has been supplied to the L.C.C. Tramways to a series of orders amounting to 550 in all. This is known as the D.K.31c, 63 H.P., self-ventilated motor, and it can be constructed with a magnet frame of the box or split type as desired, the choice of which depends upon the handling facilities in the running sheds. At the pinion end of the motor

a Skefko self-aligning bearing is used which takes both the armature load and gear end thrust, and on the commutator end a Hoffmann roller bearing is fitted. The motor is very efficiently cooled by a fan which is integral with the driving end of the armature and has a double row of blades. This parallel system of ventilation whereby the air is drawn in at one end of the motor and expelled at the other through suitable ventilating ducts has always been a feature of our D.K. ventilated traction motors. The motor at a one-hour rating has an output of 63 H.P. when taking 108 amperes on a voltage of 525, and gives an acceleration on the level of 3 ft. per second per second.

It has been found that the control gear for operating two motors of this horse power under heavy traffic conditions demands more severe duty than can be obtained from an ordinary drum-type controller owing to the high copper consumption on the latter caused by excessive wear on the fingers and segments. It was for this reason that the " English Electric " camshaft contactor controller was designed, and of this type there are now 400 in service on the London County Council Tramways. The operation of the camshaft controller is the same as on the standard type, and the pounds pull required to operate is approximately the same in spite of the heavier conditions. The main, the reversing and the braking cylinders are all constructed of a steel shaft mica-insulated, no wood or inflammable material being used. On the main cylinder are mounted a number of steel cams which close the contactor units in definite sequence, thus cutting out the starting resistance and making the necessary changes for series-parallel control of the two motors. The camshaft type of contact used gives a definite rolling and wiping action between the two contacts which ensures a positive contact pressure when closed, without increasing the turning effort at the driving handle. The contact shoes are of hard rolled copper, and are easily accessible for renewal. If necessary a complete contactor unit can be replaced very quickly. The quick action of the springs in the contactor (which arrangement is protected by a patent of this Company) prevents the burning of the contacts, and it is estimated that the copper consumption on a controller of this type compared with the

FIG. 3. CONSIGNMENT OF D.K.31C., 63 H.P. MOTORS FORMING PART OF RECENT ORDERS AGGREGATING 550 MACHINES.

standard drum controller doing the same service, would be reduced by nearly 60 per cent. This, combined with the labour involved in the upkeep of the standard controller, means a very considerable saving in maintenance. The novel method used for operating the brake cylinder has proved very successful. A double cam mounted at the bottom of the main drum automatically operates the brake cylinder when the controller lever is moved past the " off " position in an anti-clockwise direction. This provides the change in the connections for rheostatic braking only. When the controller lever is moved back to the " off " position this cylinder is automatically moved ready for power. When these operations take place no current is being taken by the motors.

The simplicity with which the controller can be wired is a very good feature as considerable time can be saved in the depôts on this operation. All terminals for outgoing cables are accessible when the controller cover has been removed. This controller can be fitted with the same type of notch regulator as is so widely used on our standard " K " controller, and which has proved so very economical in service, by avoiding the sudden overloading of the motors and misuse of the controller generally, by the drivers, and resulting in reduced current consumption and longer life to the equipment.

Tramcar Bodies and Trucks.

In the year 1900 when tramways were installed on a large scale in this country, the Car Works at Preston was one of the largest Builders of Car-bodies and Trucks, and at the present time still hold this position. The English Electric Company is the only firm in the country manufacturing the car in every detail. Thousands of cars have been built during this period and practically every town of importance in this country has cars from Preston running on the tracks to-day. Abroad, they will be found in practically every part of the civilised globe.

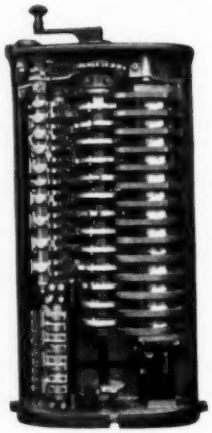


Fig. 4. Camshaft-Operated Controller.

In 1924, orders for Car-bodies included:

Cordoba.
Montevideo.
Dearne District Light Railway.
Bolton.
Nottingham.
Rochdale.
Southend-on-Sea.
West Ham.
Ceara.
Warsaw.

In February of the present year we were awarded the contract for 60 large top-covered car-bodies for the Corporation of Manchester, this being one of the largest orders that have been placed for cars for some years in this country, and a repetition of an order for 100 cars of the same type manufactured by us for Manchester a year or two ago.

Fig. 5. A group of Camshaft-operated Controllers.

THE CAR WORKS, PRESTON,
OF THE
ENGLISH ELECTRIC COMPANY LIMITED.

VIEW IN THE CAR-BODY FINISHING SHOPS.

VIEW IN THE CAR-BODY BUILDING SHOPS.

FIG. 6. TOP-COVERED VENTILATED BOGIE CAR, MANCHESTER.

Our Design Department is constantly evolving improvements in tramcars to meet modern requirements in the direction of extra comfort for passengers, improved appearance and inside finish, and also with a view to reducing weight without sacrificing strength and length of life.

Varied criticism has been levelled at the lack of progress in design of Tramway Rolling Stock, but this is unfounded, the advances having kept pace with those made on any other types of rolling stock, including railway coach construction.

Each town is a law unto itself as far as the type of tramcar to be used is concerned. The density of the traffic and the physical conditions of the towns, such as narrow streets necessitating track with small radius curves, and the gradients to be operated, are points which have to be considered. In Manchester, the physical conditions of the town and the traffic, are very favourable to the use of the type of car which has proved most popular and which can be taken as representing a typical present day example of a top-covered vestibuled bogie car. Towns which have severe gradients cannot operate this type of car with Maximum Traction Trucks owing to the wheel slip which takes place. To obtain the same seating capacity it would be necessary to use equal-wheel Bogie trucks with four-motor equipments, which is a very expensive construction. It will, therefore, be seen that towns with heavy gradients must have a four-wheel car, the size of body being proportioned to the length of truck wheelbase, the latter being governed by the sharpest curve.

Still another condition arises, that of seaside towns where most of the travelling public consists of visitors, and for this service a more luxurious tramcar should be used, giving every comfort to attract passengers. Furnishings can be utilised which would be considered unhygienic in cars in industrial towns.

The use of top-covered cars has become general, and only where 3 ft. 6 in. gauge is in existence, and with single truck cars at seaside towns do the Ministry of Transport consider this type of car unsafe. Where low bridges have to be negotiated top-covered cars have been built for this duty with as low an overall height as 15 ft., the decreased height being chiefly gained in the adoption of 24 in. wheels instead of the standard 33 in. Below we give a short general description of the cars for the duties which have been outlined above, and which have been manufactured by us.

The Manchester car, Fig. 6, has a seating capacity of 80 with an overall length of 35 ft. and height of 16 ft. 2⅝ inches. Like nearly all

FIG. 7. CAR MOUNTED ON 4-WHEEL TRUCK, OLDHAM CORPORATION.

cars now being constructed, teak framing is used, as this is the best construction to withstand our variable climate.

The underframe is of channel steel section flitched with oak packing taking the cross bars and headstock, which are also of oak, and are half lapped and bolted so as to be easily renewed. The platforms are supported on oak cantilevers flitched with mild steel plates and fitted at the end with collision fenders. Oak crown pieces are bolted to each cantilever arm forming the base for the vestibule framing. The top cover side framing pillars are reinforced with tee iron. The vestibule and top cover ends are fitted with glass, cut and curved to the sweep of the vestibule, and with this construction, contrary to expectations, no more breakages in service have occurred than with the straight glass.

We show in Fig. 7 an illustration of a car-body for Oldham Corporation, which has a seating capacity of 64 and is mounted on a four-wheel 7 ft. 6 in. wheel base truck. This body

FIG. 9. INTERIOR OF LYTHAM ST. ANNE'S CAR.

FIG. 8. LYTHAM ST. ANNE'S CAR ON THE PROMENADE, BLACKPOOL.

is of teak framing, but the construction of the underframe is different from that previously described in that the underframe and crossbars are of mild steel angles, and also the headstocks which are securely riveted together with mild steel knees. The crossbars are fitted with oak packings forming bearings for the flooring and trap doors over the motors. The car-body framing is built as separate units for sides and ends, with pitch pine solebars and oak headstocks machined to fit into the angle solebars. The platforms are supported on four cantilever arms of teak flitched with mild steel angles and are anchored to the first mild steel crossbar of the underframe. The vestibule and top cover are constructed using flat glass, and this is so ingeniously arranged that the appearance of the car suggests that curved glass has been used.

A departure from standard tramcar practice as far as the body construction is concerned was made on the cars constructed for Edinburgh Corporation. The channel steel underframe is carried round each end forming the platforms, the main saloon and platform floors being on the same level. The solebars are in two pieces riveted together at each end on the offside of the car, stiffened by crossbars of mild steel angles. The platforms are further supported by the use of tee irons. The car-body

framing is also of teak with main body pillars reinforced with pressed steel section, and special trussing arrangement is used in the car-body framing and side pillars. The platforms are built in with the main body and are vestibuled, with the exit for the passengers on the off-side of the front end of the car. This exit is used at termini for the quick unloading of passengers.

Illustrations are shown in Figs. 8 and 9 of a tramcar for Lytham St. Anne's Tramways, designed in order that the maximum of comfort should be given to passengers, and in this respect the layout in the lower saloon is different from the standard tramcar practice. The car has seating accommodation for 60 passengers, 22 being

FIG. 10. SPECIAL WORM-DRIVEN CAR FOR HULL CORPORATION.

accommodated on the transverse seats in the saloon. These seats are upholstered with leather and designed with a view to being easily cleaned. On the floor, linoleum is used in place of the usual car flooring, and although the standing accommodation is decreased the construction of the car has given very great satisfaction to the travelling public and proved very popular. The lower saloon decoration is in old oak and teak, and the upholstery on the seats is made to match.

Fig. 10 shows the Hull Corporation worm-driven car which was built to a special order and contains many new features. The platform and inner saloon floor are on the same level, and entrance into the inner saloon is by means of

FIG. 11. OLD ARRANGEMENT OF HULL CARS CONTRASTED WITH FIG. 12.

the folding door on the platform, which door acts in conjunction with the door forming a partition which closes off the mechanism when the driver is at the opposite end of the car. This necessitates the reverse staircase which has been passed by the Ministry of Transport. No bulkheads are used in the lower saloon. With this arrangement it is claimed that very quick loading and unloading can be obtained. This same type of platform and staircase can be used with cars having wheel diameters of 33 in., and the step into the lower saloon by this arrangement is not an objectionable feature. There was no truck to this car; the

FIG. 12. FREE FLOW OF PASSENGERS WITH SPECIAL ARRANGEMENT OF HULL CARS.

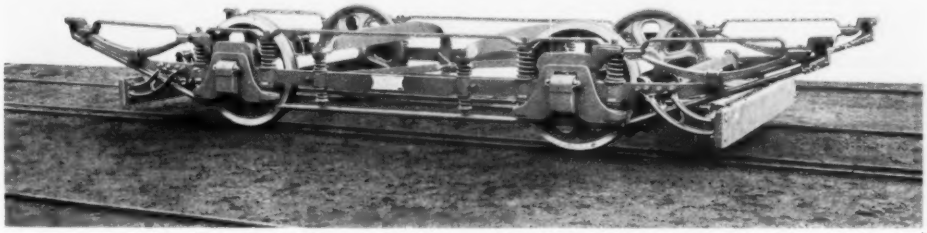


FIG. 13. "PRESTON" FLEXIBLE AXLE SPRING YOKE TRUCK.

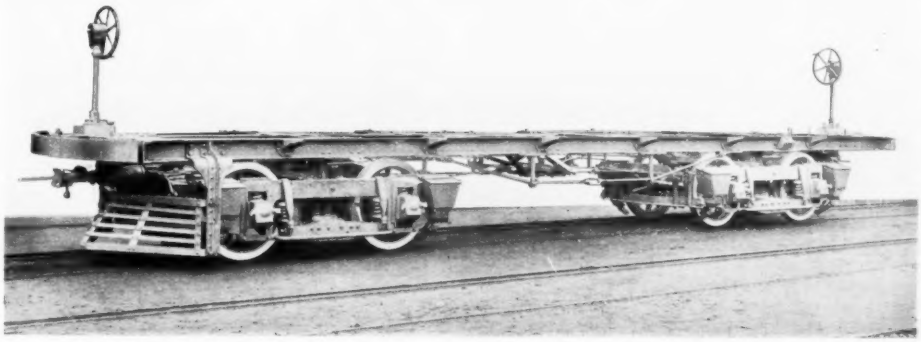


FIG. 14. BOGIE TRUCKS AND STEEL UNDERFRAME FOR A LIGHT RAILWAY CAR.

FIG. 15. SOUTHEND-ON-SEA CAR WITH "BURNLEY" TRUCKS.

FIG. 16. MONTEVIDEO CAR ON "PRESTON" FLEXIBLE AXLE TRUCK.

underframe performs this duty, and is of the design shown in the illustration.

The drive is by two 40 H.P. motors through worms on to the axles through a gear ratio of 6.25 to 1. This car has done approximately 20,000 miles, and from the reports given by the General Manager, it has proved most popular in service and a very quiet running car.

We manufacture several types of trucks for Tramcars, of which the following are representative:—

The " Burnley " Maximum Traction Truck, of which in recent years we have supplied a number to several Corporations in this country. With this type of truck the total weight on the driving wheels amounts to 80 per cent. of the car weight, thus giving the maximum adhesion possible for this type of truck, and avoiding wheel slip to a great extent. This truck is also centred on a king pin, which gives an additional facility in rounding curves and thus eliminates derailing.

The " Preston " Flexible Axle spring yoke truck, shown in Fig. 13, is a four-wheeled truck which is extensively used. It has the advantage of giving lateral movement to the axles, thus easing the shocks of the body when negotiating curves. In the design of this truck special consideration has been given to

FIG. 17. RAILLESS VEHICLE TURNING A CORNER.

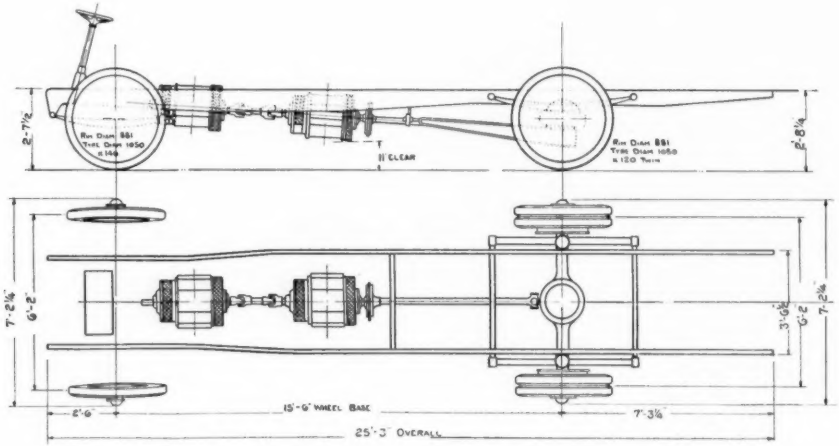


FIG. 18. GENERAL ARRANGEMENT OF LATEST DRIVE ON RAILLESS TROLLEY VEHICLE.

the elimination of as many wearing parts as possible, and where long wheel base four-wheel trucks are required, this type offers the best solution and has excellent riding qualities.

The amount of tramway rolling stock, which is continually being purchased, and the large number of schemes in prospect for Tramway extensions throughout this country and abroad, prove very conclusively that the field for tramways is as wide to-day as ever it was, and that the day of tramways is not by any means drawing to a close. We recognise the necessity for both Railless Trolley Vehicles and Petrol Omnibuses for undeveloped areas, and have designed and manufactured electrical equipments for the former and bodies for both types of transport on a large scale.

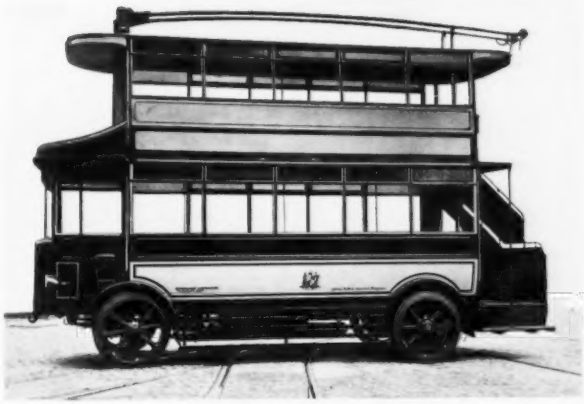


FIG. 19. BIRMINGHAM CORPORATION RAILLESS VEHICLE.

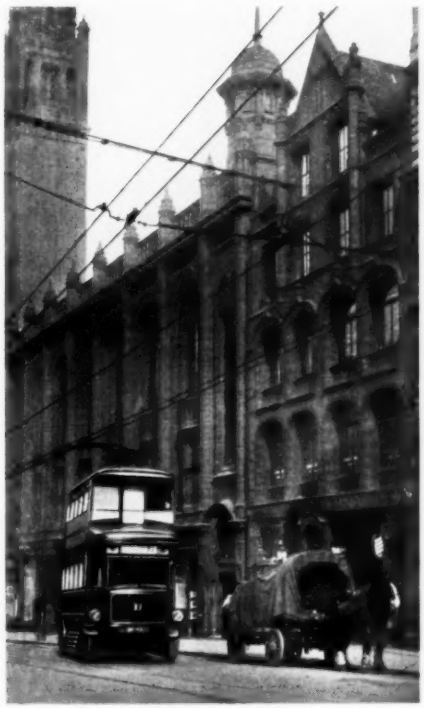


FIG. 20. RAILLESS TROLLEY VEHICLE PASSING A STANDING LORRY.

RAILLESS TROLLEY VEHICLES.

For many years we have devoted considerable attention to electrical equipment for Railless Trolley Vehicles, and many undertakings which have pioneered this type of traction have installed our apparatus.

The increasing demand for this vehicle has led us to the further development of an electrical equipment to meet the most modern ideas in this direction. Conditions were studied, and the designs we have adopted embody all the salient features necessary for a reliable and efficient railless equipment.

The new DK 99 motor, shown in Fig. 21, is of very light construction, advantage having been taken of the fact that the total weight of the motor is sprung. This motor can be used either as a single power unit with two motors side by side, or two in tandem with a flexible coupling between; to effect the latter a shaft extension is provided at both ends of the armature. The armature is carried on roller bearings which take the radial load as well as the end thrust.

It has been found advantageous on this small diameter motor to use special brush gear supported by two studs clamped to a machined surface in the frame. The studs are mica insulated, and protected by brass sleeves where they are held by clamps. Porcelain insulators are fitted on each stud between the clamp and the body of the casting to prevent surface leakage. Easy adjustment can be made to take care of any wear on the commutator.

The magnet frame is of the box type providing to a weight per horse power of only 25¾ pounds, which compares very favourably with any other motor on the market suitable for the same duty.

The construction of the motor is generally in accordance with our practice on self-ventilated motors, one of the special features being the care taken to ensure that after the armature is wound the windings do not become loose in service. The armature is banded while hot, the coils being forced into place while the in-

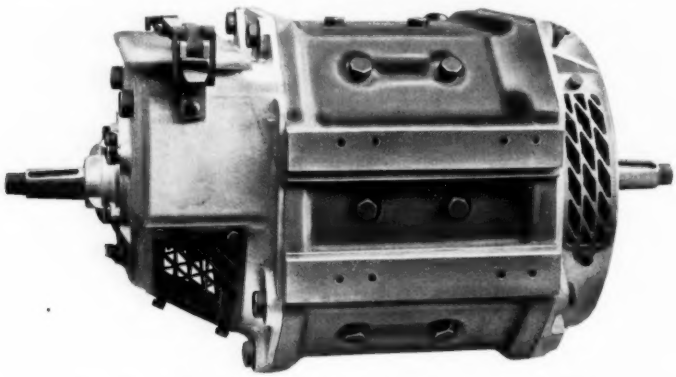


FIG. 21. DK.99 MOTOR FOR RAILLESS TROLLEY VEHICLES.

vided with facing strips for supporting the motor in the chassis. The end bearing boxes are constructed of aluminium, and are a driving fit into the frame, thus eliminating any risk of loose boxes and assuring permanent alignment of the bearings. The parallel system of ventilation which forms a feature of our tramway motor is used, and owing to the more favourable position in which a railless motor can be fixed on the chassis compared with the position of a tramcar motor, full advantage can be taken, without risk of dust and other foreign matter getting into the case, of making the inlet and exhaust ducts as large as possible.

The one-hour rating for a temperature rise of 75 deg. C. by thermometer at 500 volts is 62 amperes. The motor develops 35 horse power at this rating and has a torque at 1 ft. radius at the armature shaft of 177 pounds. The weight of the motor is 900 pounds, corresponding

sulation is soft, and held in place by temporary bands. Immediately the armature is cold these bands are removed and replaced by permanent banding of tinned steel wire wound under tension, held by clips, and finally soldered solid all round.

With the advent of heavier types of trolley omnibuses the desire that the driver should have both hands free for steering and braking purposes has resulted in our developing a foot or pedal operated controller, and the excellent results obtained on the various types of camshaft control gear led us to adopt the camshaft principle for railless vehicle control.

The controller has 10 power notches, of which 4 are running notches. The first operation immediately the pedal is depressed is to close the line breaker switch which brings in the line breaker through which the motor current passes to the controller and then to the motors.

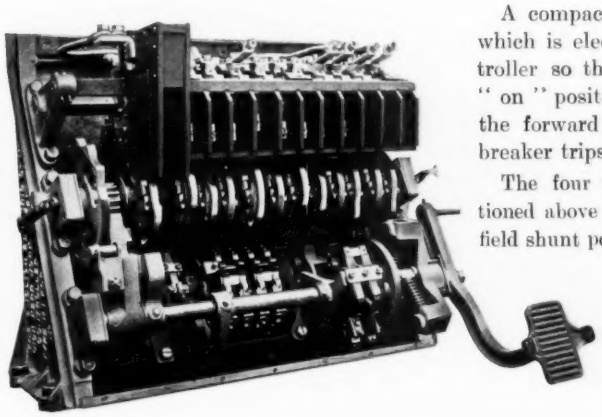


FIG. 22. PEDAL-OPERATED CONTROLLER. COVER REMOVED.

As soon as the pressure on the pedal is removed the line breaker is tripped by the switch in the controller and all disruption of the motor current takes place in the line breaker. The switch contacts in the controller deal only with the current for the line breaker solenoid. No arc shield or metallic-shield blow-out is necessary on the controller except for the transition stage, the only tips requiring renewal through burning being the two on the line breaker.

In designing the controller great care was taken to cut down the weight to the minimum allowing for a good sound construction, and also to make the controller as compact as possible. The frame of the controller is of aluminium alloy, and the cover is of Duralumin. The main cylinder consists of a steel shaft with mica insulation, upon which are mounted phosphor bronze cams of a special light construction. The pedal is pressed down against a spring which returns it to the "off" position when pressure is removed, and all the mechanism for this duty is contained inside the controller case and thus fully protected from the weather.

A compact hand-operating reverser is used which is electrically interlocked with the controller so that when the controller is in the " on " position and the reverser removed from the forward or the reverse position, the line breaker trips.

The four running positions which were mentioned above are full series, full parallel, and two field shunt positions after full parallel. The effort to operate the controller is small and the advantage of having a definite contact pressure, which the camshaft construction gives when the two contacts are closed, is very necessary owing to the vibration set up by the bad roads on which this type of vehicle has to operate. This controller is made suitable for single motor unit or series-parallel control. In the latter case a cut-out switch is provided for in the controller and interlocked in the usual way so that one motor cannot be cut out except when the controller is in the "off" position.

FIG. 23. COMPLETE PEDAL-OPERATED CONTROLLER FOR RAILLESS TROLLEY VEHICLE.